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Cooperative Assessment Program Manual
for the
Battery Manufacturing Industry

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I. STATEMENT OF PURPOSE

This Manual, which contains recommended feasible engineering and work practice controls for the Starting, Lighting and Ignition (SLI) and industrial battery manufacturing industry, has been developed through a cooperative effort by government, industry and labor. The development of the Manual is in response to the requirement set forth in the occupational health standard for lead, 29 CFR 1910.1025(e)(1)(i), that employers within the battery manufacturing industry implement engineering and work practice controls to reduce employee exposure to lead "to the lowest feasible level."

In light of the requirement to install engineering and work practice controls, to the extent such controls are feasible, it was determined that a document should be prepared to assist employers and employees within the battery manufacturing industry in identifying and implementing controls which representatives from government, industry and labor recognize as technologically feasible. However, the authors make no claim to have identified every control which is feasible in every battery plant. Conversely, some controls identified in the Manual may not be feasible in particular plants. In addition, some plants may contain atypical situations not addressed here. This Manual only contains recommendations and does not impose an obligation on employers within the industry to implement the controls identified. On the other hand, there may exist additional controls that are not described in the Manual, which under the requirement of the standard, must be installed if feasible.

The purpose of the Manual is to identify recommended feasible engineering and work practice controls. Respiratory protection programs are not addressed in the Manual. The occupational health standard for lead, however, requires that respirators be used during the time period necessary to install engineering and work practice controls and, therefore, in work situations in which engineering and work practice controls are not sufficient to reduce lead exposures to or below the permissible exposure limit of 50 ug/M^3.

The occupational health standard for lead requires that employers within the battery manufacturing industry develop and implement a written compliance program to reduce lead exposures to or below the permissible exposure limit (or to the lowest feasible level) through the use of engineering and work practice controls, 29 CFR 1910.1025(e)(3)(i). The Manual is intended to help employers develop, and employees evaluate, such plans.

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Finally, the authors anticipate that new controls will become available in the future. Employers who have not achieved compliance with the standard through engineering and work practices are obligated to evaluate these new controls as they become available and install them, if feasible. The obligation to limit employee exposure to lead requires a continued reevaluation of available control options. The authors hope that this Manual can aid employers and employees in that process, but without periodic updating, it will become obsolete.

II. INTRODUCTION

A. Audience

This Manual is intended to serve as a guidance document for employers, employees, and employee representatives in developing compliance plans as required by the lead standard. This document will also provide OSHA Area Offices with feasible engineering controls and work practices which are presently in use at various facilities.

Because of the variability in plant size in the battery industry, it is understood that many plants may not have adequate expertise in performing source identification and developing engineering controls. It is anticipated that these plants will require professional industrial hygiene or engineering assistance. This Manual will still provide general guidance and direction on procedures for lowering employee exposure to lead. In certain operations such as cleanup, maintenance and equipment upsets proper respiratory equipment must be provided.

Employers should be aware that some of the work practice recommendations such as wet down of work areas may be affected by federal, state, or local government regulations on water discharge and that additional controls may be necessary to meet these regulations.

In addition, several sources of consultative services are provided in Appendix B to aid in obtaining professional assistance.

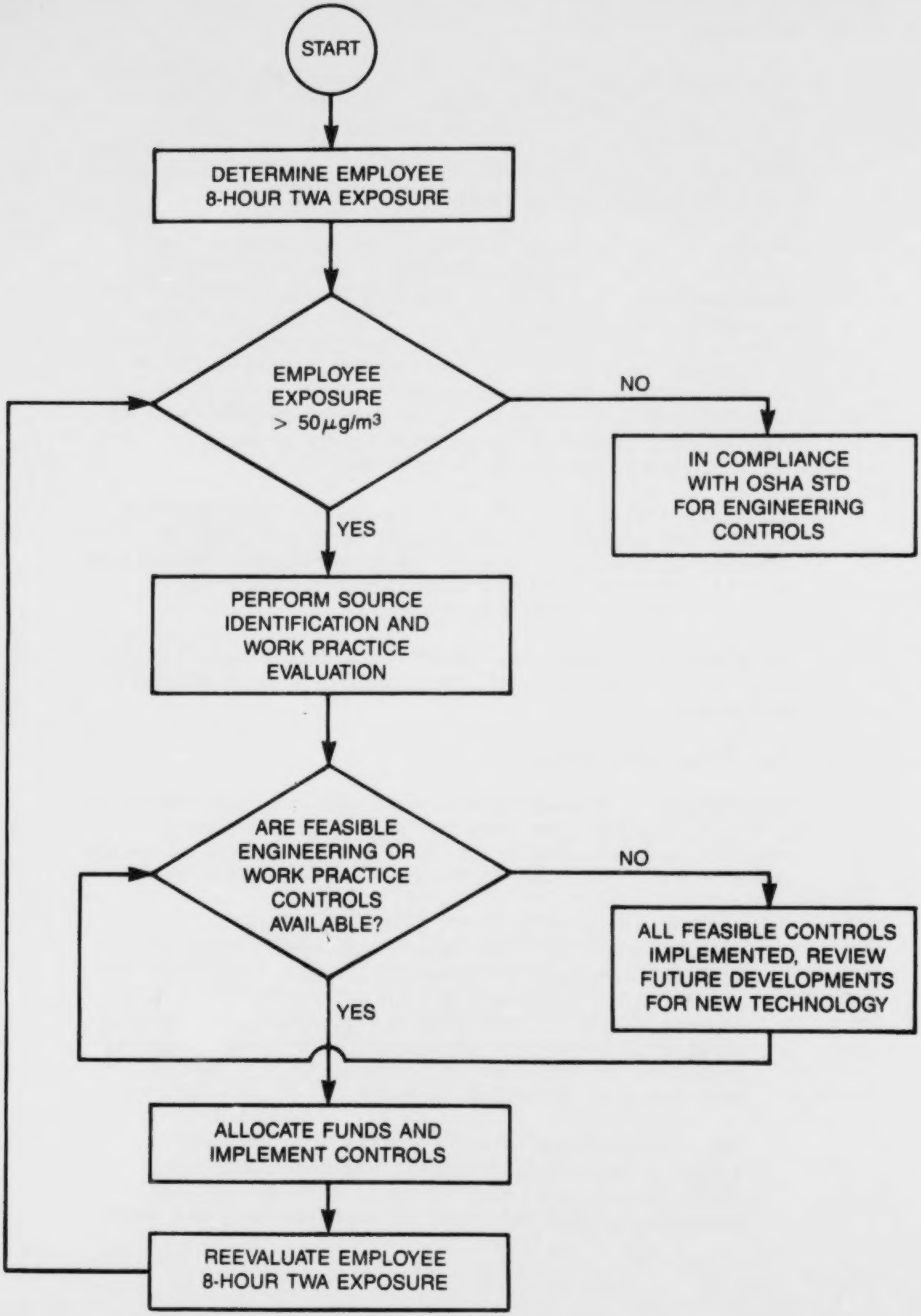
B. How to Use this Manual

This Manual is divided into several sections that should be used in evaluating the need for engineering and work practice controls. The steps involved in the evaluation are shown in the flow chart on Figure 1 and described below.

1. DETERMINATION OF EMPLOYEE EXPOSURE-Initial determination shall be made of employee 8-hour Time Weighted Average (TWA) exposure levels. This must be performed for any employees on all shifts who may be exposed to lead or who complain of symptoms which may be attributed to lead exposure. The standard sampling procedure is contained in Section III (B), Personal Monitoring to Determine Exposure.

   The information obtained normally does not provide enough information to suggest engineering or work practice controls required to lower employee lead exposure. Tasks performed by employees exposed above

FIGURE 1


START
DETERMINE EMPLOYEE 8-HOUR TWA EXPOSURE
EMPLOYEE EXPOSURE > 50µg/m3
NO
IN COMPLIANCE WITH OSHA STD FOR ENGINEERING CONTROLS
YES
PERFORM SOURCE IDENTIFICATION AND WORK PRACTICE EVALUATION
ARE FEASIBLE ENGINEERING OR WORK PRACTICE CONTROLS AVAILABLE?
NO
ALL FEASIBLE CONTROLS IMPLEMENTED, REVIEW FUTURE DEVELOPMENTS FOR NEW TECHNOLOGY
YES
ALLOCATE FUNDS AND IMPLEMENT CONTROLS
REEVALUATE EMPLOYEE 8-HOUR TWA EXPOSURE

the OSHA 8-hour TWA of 50 ug/M^3 must be further evaluated to determine feasible engineering and work practice controls.

2. SOURCE IDENTIFICATION-In order to determine which engineering controls to install, it is necessary to identify the sources of lead emissions and their contributions to employee exposure. One way this can be done is by segmenting the job of each overexposed employee into work elements. Sampling is then performed during each segment of the job to determine the relative importance of each duty. This includes but is not limited to determining the contribution of end-of-shift cleanup. Area sampling and source sampling can be used in conjunction with personal sampling to determine the contribution of background air lead levels and to identify specific sources of contamination. For this evaluation additional equipment may be required including high volume samplers and portable real-time dust monitors. These instruments can be used to sample specific job duties such as barrel dumping or hand parting of plates to determine the effect of work practices on employee exposure. Instructions on performing source identification are contained in Section III (C), Emission Source Identification.

   It is during the collection of segmented personal samples that employee work practices can be evaluated. Recommended work practices for battery making processes are listed in Section VI, Battery Processes and Controls.

3. DETERMINATION OF FEASIBLE ENGINEERING CONTROLS AND WORK PRACTICES-Where any employee is exposed to lead above the permissible exposure level of 50 ug/M^3 for more than 30 days per year, engineering controls and work practices must be implemented to reduce employee exposure to or below 50 ug/M^3 or the lowest feasible level. Section VI, Battery Processes and Controls, contains a list of feasible engineering controls and work practices for typical battery making operations. In certain operations such as cleanup, maintenance and equipment upsets proper respiratory equipment must be provided.

   After evaluating the sources of exposure and work practices, the specific means that will be employed to achieve compliance can be determined. This includes scheduling the implementation of work practices and procuring necessary engineering controls.

4. IMPLEMENTATION OF CONTROLS AND REEVALUATION-After installation of engineering controls and implementation of work practices, the employee exposure should be reevaluated to determine if compliance with the lead standard has been achieved or if additional controls are necessary. This is accomplished by going back to steps (1) through (3) and reevaluating the operation.

C. Compliance Plans

All employers must have a compliance plan as required in 1910.1025(e)(3) of the OSHA Lead Standard. Although the OSHA Lead Standard does not require submission of a compliance plan to the Area Office, for acceptance into a CAP agreement, the compliance plan must be submitted to the Area Director of the OSHA Area Office of jurisdiction for approval. This Manual can be used to develop a compliance plan and will be used as a guidance Manual by the OSHA field staff on available technology and work practices.

Written plans for these compliance programs must include at least the following:

1. A description of each operation in which lead is emitted; e.g. machinery used, material processed, controls in place, crew size, employee job responsibilities, operating procedures and maintenance practices.

2. A description of the specific means that will be employed to achieve compliance, including engineering plans and studies used to determine methods selected for controlling exposure to lead. The controls that will be implemented should be based on source identification studies previously performed. The controls mentioned in the Manual do not have to be implemented by the employer if other controls can be shown as effective or better.

3. A report of the technology considered in meeting the permissible exposure limit.

4. Air monitoring data which documents the source of lead emissions. These data may include personal, segmented, area, and source samples.

5. A detailed schedule for implementation of the program, including equipment ordering dates, equipment installation dates, and dates for implementation of work practices.

6. A work practice program which includes items required under the following paragraphs of the lead standard: (1) 1910.1025(g) Protective Work Clothing and Equipment, (2) 1910.1025(h) Housekeeping, and (3) 1910.1025(i) Hygiene Facilities and Practices. Recommended work practices by operation have been included in Section VI, Battery Processes and Controls.

7. An administrative control schedule required by paragraph (e)(6), if applicable. If administrative controls are used as a means of reducing employees' TWA exposure to lead, the employer shall establish and implement a job rotation schedule which includes: (1) name or identification number of each affected employee; (2) duration and exposure levels at each job or work station where each affected employee is located; and (3) any other information which may be useful in assessing the reliability of administrative controls to reduce exposure to lead.

8. Other relevant information.

Appendix A contains a hypothetical sample compliance plan and is only intended to show the type of information that should be included. It is not intended to be a complete program and may not be specific enough for inclusion in a CAP program. Local OSHA Area Offices should be contacted to obtain specific requirements for compliance plans.

III. EMISSION AND EXPOSURE EVALUATION

A. Characteristics of Lead Particulate

An understanding of the behavior of lead emissions is useful in selecting strategies for control. This section describes characteristics of lead emissions that are found in battery operations.

1. Lead-Bearing Dusts

The major source of lead exposure in battery manufacturing is lead dust. Any operation in which battery plates, lead scrap, or oxide is handled may be a significant source of lead exposure. Other sources of lead exposure include drossing lead pots, wind, dry sweeping, resuspension of settled dust due to vibration, foot traffic, or dislodging dust from work clothing and air currents over lead plates. Larger dust particles tend to settle out more quickly, i.e., closer to the source, than do fumes. If not controlled, settled dust may be resuspended numerous times in a local area, creating a new exposure each time.

Larger particles may not be respirable. However, these particles can be caught in the upper reaches of the pulmonary system, swallowed, and then absorbed into the blood stream from the GI tract through ingestion.

2. Lead-Carrying Mists

Lead particles can also become airborne via attachment to acid or water mists. Acid mist from battery reclaim operations can carry lead oxide and lead sulfate into the air.

3. Lead Fume

Properly functioning and operated lead pots are usually not a source of lead fume exposure. However, torching, burning, or other operations where a flame contacts lead may be a source of lead exposure. The quantity of fume produced depends primarily on the temperature to which the lead is heated. At the temperature of most lead pots, approximately 1000 degrees Fahrenheit, lead fume is not a problem. However, in torching operations or maintenance operations such as welding of lead bearing material, high temperatures may cause significant lead exposure.

B. Personal Monitoring to Determine Exposure

The personal samples are collected for a minimum of 7 hours using a personal sampling system similar to that shown in Figure 2. The sampling medium consists of a 37 mm, 0.8 u pore size mixed cellulose ester filter in a closed face cassette and is placed in the employee's breathing zone by attaching it to the employee's lapel. The pump is then operated at 2.0 liters per minute for the required amount of time. Care should be taken to avoid overloading the filter as evidenced by loose particulate.

C. Emission Source Identification

Each plant has literally hundreds of sources of emission, any of which might contribute to an employee's overall daily exposure. Because of limited technical and financial resources, it is often necessary to prioritize control needs and implement controls on a step-wise fashion. This requires planning so that controls can be applied on a true "worst-case-first" basis.

Therefore, a systematic evaluation of emissions, exposures, contributors to exposure, optional controls, and costs of controls should be made prior to any attempt to install engineering controls. This will save time, money, and provide the most cost-effective application of controls.

One approach is summarized below:

1. Employee exposures are measured to obtain an 8-hour time-weighted average.

2. For each employee exposed above the 8-hour TWA of 50 ug/M^3 all potential lead exposures in the work environment are identified. The emission source can be identified using personal, segmented, area, and source samples. The second plan view on the Figure "Source Characterization" (Figure 3) demonstrates the approach.

3. Employee work practices, work locations, and air movements are studied to determine potential contact with emissions. See the third and fourth plan views on figure.

4. Based on available information rank emission sources in order of contribution to exposure using the worksheet shown in Figure 4. If enough information is available, percentage contribution of emissions may also be estimated. Short-term samples may be taken to confirm the estimate.

FIGURE 2

PERSONAL SAMPLING PUMP

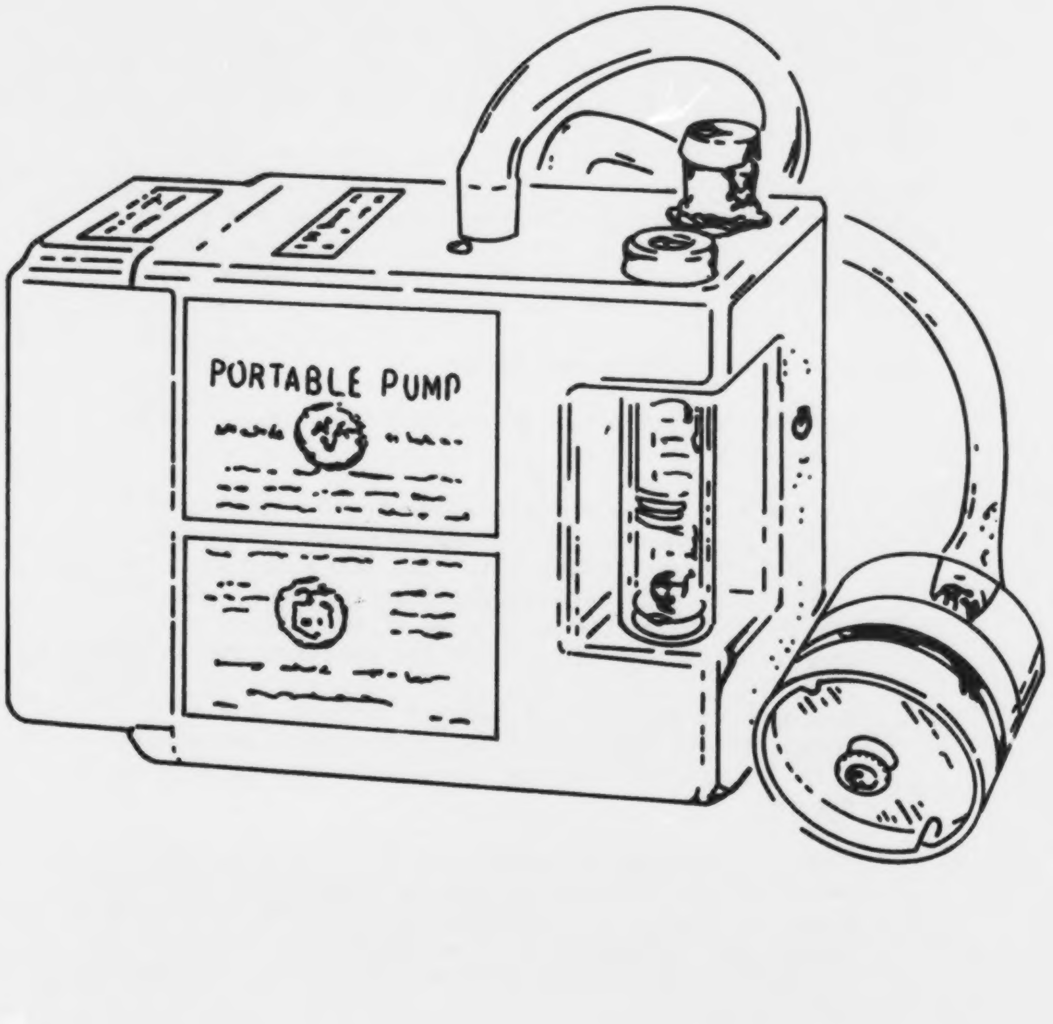
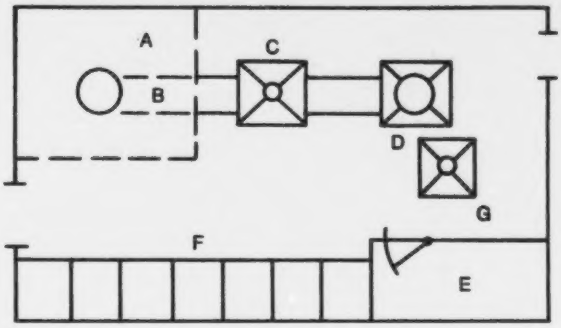

PORTABLE PUMP

FIGURE 3

BY____________ DATE __________ SUBJECT SHEET NO. ______ OF ______

CHKD. BY __________ DATE __________ JOB NO. ________

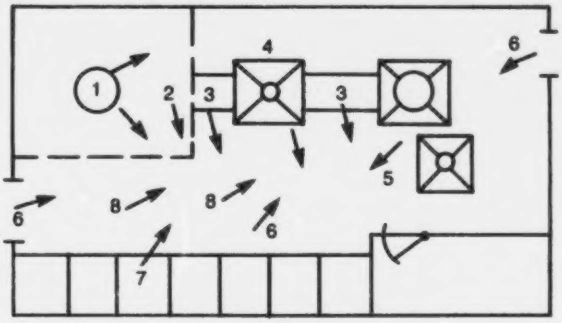
SOURCE CHARACTERIZATION
BATTERY OPERATIONS



VIEW 1

PLAN VIEW

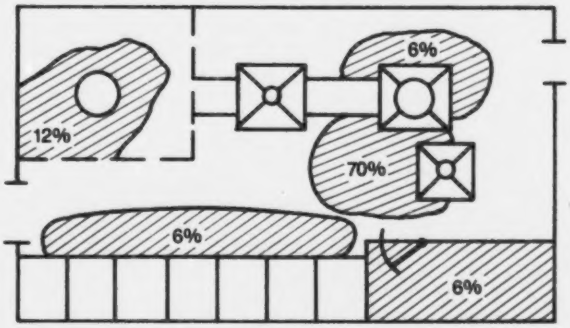
A. OXIDE MIXING AREA
B. PASTING
C. CURING OVEN
D. STACKING AREA
E. OFFICE
F. STORAGE
G. VENTILATED RACK



VIEW 2

EMISSION SOURCES

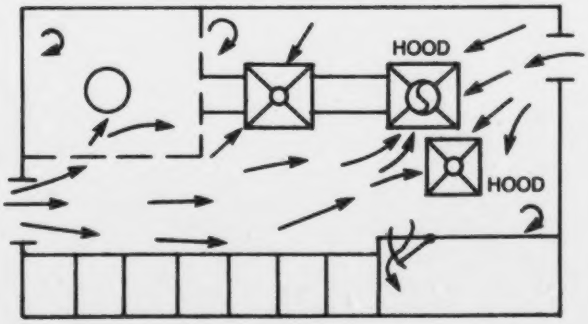
1. OXIDE OPERATION
2. PASTING
3. CONVEYOR
4. OVEN
5. FUGITIVES
6. RE-ENTRAINMENT/WIND
7. STORAGE AREA
8. MOBILE EQUIPMENT



VIEW 3

EMPLOYEE WORK AREAS

% OF TIME IN AREA
FOR OFFBEARER



VIEW 4

AIR FLOW PATTERNS

EMISSION SOURCES WORKSHEET

Name ______________________

Job ______________________ Location ______________________

Emission Source	Rank in Order of "Largest Source" of Lead to Atmosphere	Approx. % Contribution of Lead to Atmosphere	Rank in Order of Greatest Contributor to Exposure	Approx. % Contribution of Lead to Employee Exposure

FIGURE 4.

Major data inputs to this method are:

- Employee exposure levels.
- Segmented samples.
- Source and area samples.
- Work practices and geographical location of employee throughout shift.
- Employee interviews concerning emissions, work practices, upset conditions, machine down time and cleanup.
- Air flow patterns in the work area (drafts and thermals).
- Appraisals of the relative importance of emission sources.
- Evaluation of (1) material handling operations, (2) exhaust and make-up air systems, and (3) process and product characteristics.

Sample Calculation

A simple example calculation follows. If an employee works 7 hours stacking (average lead value from area samples: 60 ug/M^3) and 1 hour in the oxide plant (average lead value: 500 ug/M^3), is the oxide plant the major contributor to exposure? To "quantify" the contribution, it is possible to calculate the expected exposure level

$$\text{TWA} = \frac{(7)\times(60) + (1)\times(500)}{8} = 115 \text{ ug/M}^3$$

and the relative contribution of each major source (420 (hr x ug/M^3) vs. 500 (hr x ug/M^3)) or 45% from stacking and 55% from the oxide plant. Now to verify this estimate, we can examine the monitoring records for the employee. If the average TWA exposure level is near 115 ug/M^3, then we have some evidence to support our calculations. If the actual exposure level is higher, or lower, we should go back to the beginning and evaluate the initial assumptions (thereby possibly identifying other sources contributing to the worker's exposure, or making an adjustment in the initial exposure assumptions).

Having identified the major contributor, we can now make a judgment for control, i.e., should oxide emissions be controlled? How much control of each emission source can be achieved? What control will give the greatest reduction of lead levels versus the number of employees exposed? Figure 5 can be used as a work sheet for summarizing this information.

FIGURE 5

CONTROL OPTIONS WORK SHEET	
PLANT	SHEET NO.
	NAME
OPERATION/EQUIPMENT	DATE
DESCRIPTION OF EMISSION SOURCE	

POTENTIAL CONTROLS (DESCRIBE)	COSTS (ATTACH WORKSHEET)	REFERENCE/SOURCE

ATTACH ADDITIONAL SHEETS AS REQUIRED

IV. ENGINEERING CONTROL PRINCIPLES

A. Basic Emission/Exposure Control Principles

The following section describes fundamental principles of emission and exposure control that should be considered to limit employee exposure.

1. Process Modification and/or Material Handling

Some process and/or material handling modifications may be feasible to eliminate or reduce the generation of lead emissions: minimize plate handling, lower lead pot temperatures, consider means of decreasing dross formation and surface generation of dust on plates, and modify plant layout to reduce material handling or reentrainment of settled lead dust.

2. Mechanize the Process

Lead exposure can be reduced in some cases if machines are selected to perform high-exposure tasks so that employees may be removed from the area. Replace drum handling with mechanical conveyance, tub handling with a vertical array, or manual with machine parting.

3. Isolate the Process

To prevent cross contamination of clean areas in the plant, it is desirable to isolate processes generating significant emissions. A physical barrier will contain lead emissions and reduce their spread. Thus, fewer people are exposed, and the number of emission sources contributing to exposure in any one area will be reduced. This simplifies exposure evaluations, and makes the identification and control of major sources easier. Reclaim operations are often isolated from other plant operations.

4. Enclose the Emission Source to the Extent Feasible and Provide Local Exhaust Ventilation

Occasionally it is possible to enclose or isolate a specific emission source, e.g., paste mixing, pasting line conveyor, COS machine, or dross handling. Because enclosures are seldom air tight, a negative draft exhaust system is often applied to the enclosure. One of the most common ways to control lead emissions is to provide local exhaust ventilation at the point of emission generation. Capturing emissions at their source reduces the potential for emissions to disperse into the air. It also prevents secondary employee exposure created by the reentrainment of settled contaminants.

The capture velocity of an exhaust hood must be great enough to prevent lead fumes or dust from escaping the air flow into the hood. The air flow should have enough velocity to carry fume and dust particles into the hood and to overcome the disrupting effects of cross drafts and other random air movements. The velocity required to accomplish this will vary from application to application. Restrict the use of recirculation heaters or man cooling fans which can overcome local exhaust ventilation.

5. Establish specific zones of "clean/controlled" and "contaminated" air.

   Clean areas are intended to be controlled through direct emission controls and housekeeping. These areas exhibit low ambient lead levels. Employees in contaminated areas can be protected by supplied-air service cabs, islands, stand-by pulpits and control rooms, supplemented by personal respiratory protection. For example, emissions in oxide manufacturing areas are traditionally difficult to control. In these areas emissions occur and personal exposures are controlled by automated processes, enclosed and ventilated operator's equipment cabs, controlled-environment stand-by rooms, and by personal protective devices.

6. Provide a "contaminant free" atmosphere for workers.

   The average daily exposure of workers to lead can be reduced by providing clean areas such as operating station stand-by pulpits, or breakrooms and lunchrooms that are supplied with fresh filtered air. By spending time in a relatively lead-free area, the employee's time-weighted average exposure can be reduced. Another popular application of this principle is the "supplied-air island", a shower of fresh filtered air supplied to the breathing zone of the employee at the workstation.

7. Provide sufficient space for process and control equipment.

   Allow sufficient space for hoods, duct work, control rooms, maintenance activities, cleaning and equipment storage.

8. Minimize wheeled-vehicle dust generation.

   Wheeled-vehicles are significant sources of secondary lead emissions. Where wheeled-vehicle transport is used, emissions can be reduced by paving all surfaces, keeping surfaces free of accumulated dusty materials, reducing vehicle travel distances and speed, and by redirecting vehicle exhaust and cooling fan discharge. Appropriate paving material such as concrete should be selected after considering factors as load, use, and care of surface maintenance. Coatings may be applied to some surfaces to facilitate wash down of roadways.

9. Provide make-up air systems for enclosed buildings.

   All exhaust or dilution ventilation systems also require replacement air (known also as "make-up" air systems). If the replacement air system is well designed and integrated into natural and comfort ventilation systems, more effective control of exposures can be expected. For example, replacement air outlets should be placed so clean air flows from the outlet across the employee, towards the emission source, and to the exhaust. This technique is often used with supplied air islands and places the employee between the clean incoming air and the emission source.

10. Maintenance.

    All exhaust, dilution and make-up air ventilation systems must be properly maintained in order to effectively control air contaminants. A regular preventive maintenance program, including periodic checks are required by section (e)(5) of the OSHA Lead Standard. In addition to maintaining general ventilation systems, process equipment must be maintained to eliminate spillage of material and fugitive emissions. Appendix D contains information on making ventilation measurements and maintaining a ventilation system. For details on ventilation theories see Appendix C and Industrial Ventilation A Manual of Recommended Practice published by the American Conference of Governmental Industrial Hygienists.

B. OSHA Requirements for Mechanical Ventilation

29 CFR 1910.1025 (e)(5)(i) describes testing procedures for mechanical ventilation systems:

> (i) When ventilation is used to control exposure, measurements which

demonstrate the effectiveness of the system in controlling exposure, such as capture velocity, duct velocity, or static pressure shall be made at least every 3 months. Measurements of the system's effectiveness in controlling exposure shall be made within 5 days of any change in production, process, or control which might result in a change in employee exposure to lead.

(Note: These are legal minimum requirements of the standard. However, more frequent measurements or observations should be made.)

(ii) Recirculation of air. If air from exhaust ventilation is recirculated into the workplace, the employer shall assure that (A) the system has a high efficiency filter with reliable back-up filter; and (B) controls to monitor the concentration of lead in the return air and to bypass the recirculation system automatically if it fails are installed, operating, and maintained.

By performing these tests routinely, the company can detect changes in the efficiency of the system. Routine checks of duct velocities and static pressures should be supplemented with maintenance checks of the belts of motors and fans as well as the rpm of the fan.

V. WORK PRACTICE PROGRAM IMPLEMENTATION

A. Introduction

Although the lead standard emphasizes engineering controls as a means of achieving compliance, work practice controls are essential to a successful lead control program. Engineering controls can be defeated by poor work habits, maintenance, housekeeping and personal hygiene. This is often observed when employees operating the same equipment on different shifts have significantly different airborne lead exposures.

These programs, although often overlooked, represent good managerial practice as well as good common sense; they are "cost effective" but require a responsible and cooperative attitude on the part of management and active participation on the part of employees. Top management's attitude toward safety and health is reflected in the attitude of line supervisors. Likewise, if supervisors do not enforce these programs employees attitudes will suffer. Fostering good health and safety attitudes can be accomplished through; (1) a cooperative atmosphere in which employees participate in the programs, (2) formal training and educational programs, and (3) emphasizing plant safety and health programs. Motivating employees and obtaining their trust is necessary in order to have an effective program.

Work practice programs cannot be simply "installed" like many ventilation systems. Like ventilation systems, they must be maintained and continually checked to insure that they are functioning properly. These programs are the responsibility of management and employees. Programs should be established to teach, encourage and supervise "good" (i.e. low lead exposure) practice. The following suggestions can be useful in implementing the attention to detail necessary for a successful lead exposure control program.

B. Management Responsibiltiy

For any effort in the workplace to be successful, top management must make a commitment and communicate that commitment to employees. An effective lead control program requires the cooperation of all participants - management, supervisors, and workers. Adequate time, resources, and personnel must be devoted to it. If lead exposure is to be controlled, the control efforts must be integrated with the production process from top management to each individual employee. (In one company, management must sign off on weekly ventilation check measurements.)

Supervisors must be trained in and made responsible for work practices and lead exposure in areas under their jurisdictions.

Effective programs, including those for cleanup, respirators, and spill/upset conditions usually require a written document. It should be written in such a way that all can understand the answers to the basic questions: WHAT, WHY, WHERE, HOW, WHO, and WHEN. Written procedures make the requirements part of the job, can be reviewed by supervisors and employees periodically, and can assist in counseling and enforcement. Proper work habits should be identified through a Job Safety and Health Analysis and integrated into the process specification describing how the whole job is to be done. Part of the written procedures should include records of ventilation tests, inspections, and repairs which can be reviewed by health and safety committees as an indicator of program effectiveness.

A written program without effective communication to the employees will not function properly. Communication means more than handing each employee a ten page document on work practice procedures. It includes proper training so that employees understand what is required and know how to obtain satisfactory performance. Training should include supervisors and should utilize employees who have kept their lead levels under control to explain successful work practices. Plant walk throughs and group meetings to discuss health problems can be included. Counseling programs have been used successfully in some plants to focus on personal hygiene and work practice problems.

Retraining and program evaluation should be provided on a periodic basis which includes a measure of evaluation using baseline value and ultimate goals.

C. Employee Participation

An effective work practice program requires supervisor and employee acceptance. A person who has something to say about a program and knows about the results is more likely to actively support the activity than one who has not participated. This also helps to build employee trust and gains the commitment necessary to make a company sponsored health and safety program successful.

Employee participation includes the notification, observation of monitoring and training requirements of the lead standard. These should be used to encourage cooperative efforts through counseling programs, suggestions, and other means.

Health and safety committees are one way to enlist employee participation. Committees have two basic functions: (1) creating and maintaining an active interest in safety and health, and (2) communicating health and safety considerations to management and employees. However, they will only be successful if management supports the decisions and recommendations of the committee.

The committee should include management, supervisors and production workers. If safety and health or medical staff are employed by the company, they should be included. Committees must not become so large that they are unwieldy. A proper balance of employer and employee members should be present and a free exchange of ideas and information must be fostered.

Some of the committee functions should include the following:

1. Frequent unannounced inspections of plant operations. Investigations of accidents, injuries, and illnesses.
2. Monitoring airborne contaminants and reviewing work practices during normal plant operations.
3. Perform a safety audit by identifying potential hazardous chemicals and plant safety problems.
4. Obtain background information on past problems in the plant and programs to eliminate them.
5. Work with employees to assist them in working safely and to follow work practices recommended for the job.
6. Keep written records of inspections, recommendations to plant management, and meetings and corrective actions.

VI. BATTERY PROCESSES AND CONTROLS

The following are descriptions of processes and illustrations of engineering controls observed in various battery manufacturing facilities during visits to determine feasible engineering controls. The illustrations are intended to be used as guides for design purposes and apply to typical operations observed. For specific manufacturing facilities, these designs may not be feasible due to constraints in process equipment or inadequate space. All conditions of operation cannot be categorized and because of special conditions, i.e., cross drafts, vehicular movement, higher background levels, or inadequate work practices, modifications to operations or higher capture velocities may be necessary.

A. Oxide Production

1. Process Description

Lead oxide may be purchased or produced by either a Ball Mill or the Barton Process. The oxide may be used at the production location or loaded into trucks or drums for shipment.

a. Ball Mill. In the Ball Mill process, pigs or bars of lead are fed into a rotating ball mill. The lead is ground into smaller particles by friction due to rotating against each other. The oxygen in the air, assisted by the frictional heat generated by the tumbling lead, reacts with the lead to produce lead oxide. The lead oxide that forms on the surface of the lead is removed by abrasion and transported to a particle classifier and then to a collection system for distribution.

b. Barton-Like Process. In the Barton-Like Process blocks of pure lead are fed into a heated melting pot. The molten lead then flows into the Barton pot where it is vigorously agitated to form extremely small droplets of lead. The droplets are oxidized by the airstream flowing through the pot, separated by particle size, and carried to a collection system.

2. Major Sources of Exposure

a. Since the oxide mills, classifiers, and storage hoppers are normally under negative pressure, most airborne lead levels are due to system upsets resulting from air surges, plugged systems, or leaking equipment. Sources of oxide spills or leaks include: (1) trunnion seals, (2) bearing seals, (3) conveying systems, (4) transfer points, and (5) improper air flow resulting in "puffing" oxide at the mill inlet.

b. Drossing the lead pot used in the Barton Process and maintenance operations that require entry into the pot for cleanout.

c. Drumming operations and oxide transfer in barrels.

3. Secondary Sources of Exposure

a. Collection of oxide quality control samples.

b. Cleanup operations.

c. Vehicular traffic in adjacent roadways and work areas.

4. Engineering Controls

Two types of engineering controls can be used to reduce operator exposure at oxide mills. These can be used as separate, distinct systems or used in combination. They are local exhaust ventilation at points of contaminate generation and isolation of the process.

a. Local Exhaust Ventilation

(1) Hood enclosure for lead melting pot and dross pot or barrel.

(2) Exhaust ventilated sampling and process test station. Replacement of manual sampling by automatic sampling.

(3) Tightly enclosed conveying systems with ventilation at transfer stations.

(4) Exhaust ventilation around agitator shaft or air intake of Barton pot to prevent puffs of lead oxide from escaping into the room air. A duct may be placed over the air intake which will contain the volume of the puff and prevent it from entering the workplace.

(5) Local exhaust ventilation around any significant leak which cannot be corrected.

(6) Exhaust ventilated and completely enclosed drum filling operation.

(7) Local exhaust ventilation for loading tank car or a pressure relief valve to the screw conveyer to vent dust generated during the transfer operation.

b. Isolation

(1) Physical separation by walling off this operation in an area of negative pressure from rest of the plant.

(2) Positive pressure control room for operator with television cameras to monitor operation of oxide mill.

c. Other

(1) Replace where feasible, operations involving high exposure with a safer operation: (a) replace barrel handling with pneumatic conveyance, (b) replace manual sampling with automatic sampling.

(2) Install a vertical classifier ahead of normal classifier and oxide collection equipment to reduce "puffing" for Barton Process equipment. Note: contact Kenneth Pike, East Penn Manufacturing Company for information.

(3) Storage tanks should be insulated or protected from the weather to prevent water condensation on the inside walls and possible oxide fires.

(4) Mechanize feeding lead pots or mills.

5. Work Practices

a. Notify supervisor of any oxide leaks and perform any temporary repairs immediately.

b. Vacuum any oxide spills immediately. Water should not be used in the mill area for dust suppression due to the possibility of oxide fires and the mixing of water and molten lead.

c. A written schedule of inspections should be developed for oxide mill operators. This should include the inspection of equipment such as overhead ducts and rotary valves weekly for leakage.

Leading equipment should be inspected daily until the leak is repaired and under control.

d. Drum filling must be performed inside ventilated hoods or enclosures. The exterior of drums should be vacuumed or wiped off before transferring to storage or other areas. Drums should be capped before vacuuming.

e. Ascertain that ventilation is working properly. This can often be done by monitoring air flow through the system.

f. Each shift, cleanup surfaces of equipment and floors using vacuuming whenever possible.

B. Grid Production and Parts Casting

1. Process Description

Grids used in battery manufacture are produced either by casting or by expanded metal.

a. Grid Casting. Grid casting involves melting pigs of lead alloys at approximately 1000 degrees Fahrenheit. In the grid casting machine, molten lead is poured automatically into molds. A gas flame is used to keep the lead flowing or produce a non oxidizing atmosphere above the mold. The grid metal can contain one or more of the following: antimony, arsenic, tin, calcium, cadmium and trace amounts of selenium, copper, nickel, tellurium and bismuth. The molds are cooled and the grids that are formed are trimmed, inspected, and stacked.

b. Grid molds are usually cleaned by scraping them with a wire brush which may cause lead adhering to the mold to become airborne. The mold is then sprayed with a cork mold release agent to aid in separating poured grids.

c. Parts Casting. Small parts are usually cast using an antimonial lead. These parts including battery terminal posts, straps and connectors and lead burning bars are cast in a manner similar to grids. Some plants use mechanical parts casting machines while others use manual pouring. Employee exposure in parts casting are the same as in grid casting and the same controls can often be used.

d. Expanded Metal. Sheets of lead alloy are purchased or manufactured onsite. Rolled sheets of lead alloy are cut on a die, expanded, and pressed for proper thickness to produce the grids. The expanded metal sheet is then fed directly to the pasting machine.

2. Major Sources of Exposure

a. Drossing the lead pot.

b. Operations where a flame contacts lead, such as cutting out a frozen pot, high levels of lead fume are generated.

c. Fuel powered fork lifts blow settled dust on floors and cause a reentrainment problem.

d. Manual handling of pigs which have a coating of lead oxide due to oxidation. A high exposure can occur when the pig is pushed into the lead pot and lead contaminated gases escape the enclosure. A long handle push rod or mechanical system can be used to lower employee exposure.

3. Secondary Sources of Exposure

   a. Airborne migration of lead dust from other areas such as the pasting line.

   b. Using lead contaminated pallets that have not been cleaned off after return from the pasting department.

   c. Normally mold cleaning is not a source of exposure unless some type of rotary sander is used.

   d. Cleaning the dross ladle outside the hood or storing it in an area where the oxide on the ladle can be suspended in the air.

   e. Manual handling of grids may be a hygiene problem although it will not contribute significantly to airborne lead levels.

4. Engineering Controls

   a. Local exhaust ventilation on the lead melting pot and the dross pot. Dross with a ladle having holes which allow lead to drain back into the pot during dross removal.

   b. Running the lead pot at a minimum temperature to reduce dross formation.

   c. Providing a supplied-air island at the drossing station.

   d. Providing local slot ventilation or a ventilated torch for cutting out frozen pots.

   e. Suspend plastic curtains to separate the casting areas from outside sources of contamination such as vehicle traffic.

   f. Isolate the lead pots from casting operations.

5. Work Practices

   a. Make sure ventilation is working properly.

b. When handling dross do it carefully within a ventilated enclosure. Keep the doors closed on the dross cabinets when drossing into the containers. Do not store dross uncovered in front of an open door or window or near areas of vehicle traffic since wind currents will easily disperse the powdery dross. Any waste drums should be cooled under exhaust ventilation, enclosed completely or covered with a poly bag prior to storage. Do not add sawdust to the dross. The generated smoke will help to spread lead dust.

c. Dust suppression techniques should be used on floors around work areas. These techniques include keeping floors wet, using sweeping compounds or vacuuming.

d. Keep drosses from calcium and antimonial alloys separate and dry since arsine and stibine gases could be emitted.

e. Slide, don't throw bars of lead into the casting pots.

f. Keep floor areas and work surfaces around lead pots and lead storage areas clean of oxide and lead.

g. Use separate pallets for grid storage and plate storage. This minimizes the introduction of dried paste into the grid casting department. Layer boards can be painted different colors to indicate the departments where they should be used.

C. Paste Mixing

1. Process Description

a. Lead oxide is added to the mixer and water is blended in to form a thick paste. Dilute sulfuric acid is added slowly with mixing and cooling until the desired consistency and density is achieved. The sulfuric acid forms lead sulfate, which in addition to expanding the paste gives it greater porosity, supplying a necessary binding cement so the pasted plate can be handled without loss of significant amounts of material.

b. Negative plates are made in a similar manner except that "expanders" are added. These may include a mixture of lead oxide, barium sulfate, and an organic material such as channel or carbon black. Expanders are necessary in negative plates to activate the plates at low temperatures and high rates of discharge. They also inhibit coalescing or shrinkage of the negative plate during its life.

c. Ingredients are usually stored in tanks above the mixer and the appropriate amounts metered into it during each batch mixing cycle. With a vertical array large oxide storage tanks are located above the paste mixers on the upper level of the three level tower. An automatic delivery system allows gravity feed of lead oxide to the mixers located on the second level. Directly below each mixer, a pasting machine receives lead paste via a conical feed hopper (feeder cone). This arrangement eliminates extra handling of paste required with the tub paste feed system and the associated spillage and housekeeping problems.

d. With tub transport of paste, the paste is mixed in a similar manner as in the vertical array. Once produced, the paste is dumped into a container (tub) and transported to the pasting machine. The paste is then manually "mucked" into the pasting machine using a hoe or similar device from the tub which is elevated to a level above the paste machine feed.

2. Major Sources of Exposure

a. Poor system integrity or leaking equipment including: (a) oxide conveyance, (b) weigh hopper, and (c) mixer door seals.

b. Inadequate ventilation on the mixer due to exhaust vents being plugged by moist material.

   c. Testing of oxide or paste.

   d. Adding expander containing lead to the mixer.

   e. Manual scraping and cleaning of mixer during cleanup or change over of type of paste (positive or negative).

   f. Reentrainment of dried and settled lead on buckets, cone feeder, or other equipment.

3. Secondary Sources of Exposure

   a. Inadequate ventilation on drying ovens may cause rising air currents that expose the mixer operator.

   b. Folding lead containing expander bags for disposal outside of a ventilated enclosure.

   c. Sampling oxide or paste.

   d. Dried oxide on gloves and hand tools.

   e. With an empty cone feeder, a chimney effect occurs due to heat rising from the pasting machine that dries out oxide and suspends it in the rising air currents.

   f. Drafts and air currents caused by rotating or moving equipment or motor drives.

4. Engineering Controls

   a. Maintain system leak free and keep weigh hopper, delivery system, and mixer continuously under negative pressure.

   b. Provide an exhaust ventilation at test station, sampling port on mixer, and expander handling areas.

   c. Provide a supplied-air island (SAI)/laminar flow at the operator work station.

   d. Design cleanout hatches on exhaust system to facilitate cleaning.

   e. Mixer equipment may be arranged in a vertical array with the cone discharge directly over the paste machine feed hopper to eliminate manual handling of paste. Keep the mixing platform tightly enclosed and under negative pressure.

5. Work Practices

a. Make sure ventilation is working properly. Check that exhaust vent damper control is in working order so that moist air from the acid addition cycle does not go into the dry dust collector side of the system.

b. Wash down equipment and floor often so that settled dust cannot be reentrained. Especially important is keeping clean the tubs used for transporting oxide. Keep floors continuously wet if possible.

c. Watch for oxide leaks and immediately report them to the supervisor.

d. Keep all openings and doors to the mixers closed to reduce air contamination.

e. Report all mechanical problems to the supervisor. These may include defective seals at oxide transfer points, holes in the mixer, a broken seal on the oxide screw conveyer. These should be repaired promptly to avoid contamination of the area.

f. Handle expander containing lead oxide carefully. Open it in a ventilated enclosure, preferably in the mixer, empty slowly into the mixer, and carefully discard the empty bags in a closed container. Do not shake or crush in such a manner as to create an airborne exposure.

g. Don't hammer the mixers, cone feeders, hoppers, ductwork or any other paste/oxide vessel with tools to loosen oxide or paste.

h. Wipe down exterior of mixer with a light coat of oil.

i. Use a central vacuum drop to remove any oxide spills or leaks at the oxide delivery area and at the mixing operator station.

j. Don't use fabric (burlap) to cover plates or tubs of paste. Plastic or some other material which will not become heavily contaminated with oxide should be used.

k. During cleanup of the mixer, make sure the power is shut off and locked out. Use high pressure water spray if possible instead of a putty knife. If a scraper or putty knife must be used, a long handle may reduce operator exposure. If the operator must place his breathing zone in or near the mixer, a properly fitting respirator must be worn.

l. Quality control sampling and testing should be performed at a ventilated work station. Equipment should be kept clean and tools such as a putty knifes or spatulas kept in a pail of water after use.

D. Pasting

1. Process Description

a. Lead oxide paste is applied to the grid panels in a pasting machine to fill the interstices of the grid. The plates are then rolled and flash-dried in an oven to remove excess water. Workers remove the partially dried panels from the conveyor and place them on pallets. This operation is often called "take-off", "offbearer", or "parting" if the panels are parted at the same time.

b. Pasting with expanded metal is similar to a normal pasting machine with the exception that "paper" is applied to both sides of the expanded metal. The paper holds the paste in the interstitial spaces of the grid until the paste has hardened after hydroset. The paper is selected so that it does not affect the performance of the plate and remains on the plate throughout its life. After pasting, the material is die cut and enters a flash dryer.

c. As the plates pass through the remaining processes, they appear to be less dusty and the dried paste is held in place with much less shedding. Expanded metal has been successful for calcium-tin-lead batteries and has had only limited success for positive plate grids. Expanded metal can be used economically only when the product line is stable and few changeovers are required. Also, an additional 10 feet of space is required ahead of the pasting line before expanded metal can be installed for staging take up spools of expanded grids.

2. Primary Sources of Exposure

a. Pasting Operator

(1) Paste drying on mixer, cone feeder, paste transfer equipment, pasting machine, floors, and adjacent areas.

(2) Scraping oxide off the hopper and exterior of cone feeder during cleanup and upsets.

(3) Improper ventilation on the drying oven and failure to enclose the oven completely to the floor. The oven should be enclosed all the way to the floor since the oven or conveyor chain may stir up or resuspend settled lead

oxide dust. The oven must also be cleaned out regularly since buildup of oxide dust may cause an imbalance in the ventilation and raise airborne lead concentrations.

(4) Manual handling of paste accumulated on the floor or from plate squeezings prior to entering the oven.

b. Take-Off/Offbearer

(1) Dry plate handling or moving plates in and out of work station.

(2) Dirty equipment, racks, and floor.

(3) Brushing of plate lugs during parting.

(4) Improper handling or disposal of scrap plates.

(5) Inadequate capture velocity for tamping plates.

3. Secondary Sources of Exposure

a. Pasting Operator

(1) Rotating drives and motor cooling fans cause dispersion of oxide which has settled on housing.

(2) Contamination of gloves, clothing and tools with oxide which upon drying can become suspended in the air.

(3) Operation of controls located near the breathing zone with lead contaminated gloves.

b. Take-Off/Offbearer

(1) Clearing jam-ups in equipment and other upsets.

(2) Improper disposal of scrap plates i.e. throwing into an unventilated barrel.

(3) Contaminated clothing.

(4) Operation of controls located near the breathing zone with lead contaminated gloves.

4. Engineering Controls

   a. Pasting Operator Station

      (1) Supplied-air island providing 100-150 feet per minute (fpm) at operator's breathing zone. Plastic skirting may be provided to increase efficiency of hood.

      (2) Maintained negative pressure in drying oven ventilation (ventilation efficiency decreases if oxide is allowed to buildup in the bottom of the drying oven).

      (3) Exhaust ventilation around paste machine feed hopper to prevent dust generation during scraping, cleanup, operation.

      (4) Exhaust ventilated QC testing station.

      (5) Use totally enclosed fan cooled motors to reduce dust generation.

   b. Take-Off/Offbearer

      (1) Slot/down draft ventilation at take off station.

      (2) Supplied-air island at operator's work station.

      (3) Put shelves inside hood or in a ventilated area so plates cannot be stacked in an unventilated area.

      (4) Exhaust ventilated plate racks.

      (5) Place a piece of plexiglass across front of the hood so that operator can observe work and so ventilation works more effectively. Plexiglass should be installed at an angle so that it cannot be used as a shelf for storing plates.

      (6) Provide exhaust between oven and take off work station to prevent dust contamination generated from exiting plates and conveyor chain.

      (7) For industrial batteries, ventilation may be required which is not always necessary for SLI batteries. This includes rack ventilation, a ventilated lug breaking station, and a

directed air system through the operator's breathing zone. The directed air system includes a water floor with a space above the water floor for down draft ventilation. An SAI above the operator work station supplies air for the directed air system.

(8) Use a guide bar (belly bar) to prevent employee from leaning up against equipment. Design to avoid back injury.

5. Work Practices

a. Pasting Operator

(1) Cleanup paste spills immediately. Report mechanical problems to supervisor.

(2) Dust suppression techniques should be used on floors around work areas. These techniques include keeping floors wet, using sweeping compounds or vacuuming.

(3) Change clothes daily. An apron should be provided to prevent clothes from becoming contaminated.

(4) Provide gratings for walking surfaces. Wash boots with water before leaving the area.

(5) Clean equipment at least each shift. Use long handle scrapers or putty knives and a water washdown. Control pressure and direction of spray to prevent splashback.

(6) Coat equipment with peanut oil/water emulsion to aid adhesion of dry oxide and to facilitate end of shift equipment cleanup.

(7) Provide central vacuum drops for cleanup.

(8) Try to keep employees breathing zone away from oxide or dry paste. Place machine controls at machine level, not overhead near hopper.

(9) Shovel wet paste so as to minimize splatter. Keep gloves and hand tools wet.

(10) Keep doors to oven closed at all times.

(11) Place scrap plates into a ventilated barrel or box and dispose properly: cover with plastic

bag before moving, or if a wax coated cardboard box is used, close and remove to storage.

(12) Leave work shoes or shoe coverings in pasting department to avoid transport of lead throughout the plant. Wash shoe covering before leaving area.

(13) Prohibit man cooling fans or open doors and windows which cause cross drafts or thermals and destroy effectiveness of local exhaust.

b. Take-Off/Offbearer

(1) Make certain that ventilation is working properly.

(2) Vacuum table, equipment and racks to prevent accumulations of oxide.

(3) Dust suppression techniques should be used on floors around work areas. These techniques include keeping floors wet, using sweeping compounds or vacuuming.

(4) Keep all oven and cleanout doors closed.

(5) Break plates inside of hood or over ventilated tamping stand. Do not break on a metal plate or solid board. If possible, provide a see-through plastic plate between operator's breathing zone and the conveyor and tamping stand.

(6) When brushing lugs or the edge of the panels or plates to remove adhering oxide, brush toward hood ventilation.

(7) Use smooth, impervious surface for layer boards and racks since they can be cleaned more easily.

(8) Provide belting or plastic sheets around operator work station to minimize turbulence and improve efficiency of hoods.

(9) Place scrap plates into a ventilated barrel or box and dispose properly: cover with plastic bag before moving, or if a wax coated cardboard box is used, close and remove to storage.

(10) Prohibit man cooling fans or open doors and windows which create thermals or disrupt local exhaust ventilation.

(11) Leave work shoes or shoe coverings in pasting department to avoid transport of lead throughout the plant. Wash down boots before leaving area.

(12) Use separate pallets for grid storage and plate storage. This minimizes the introduction of dried paste into the grid casting department. Layer boards can be painted different colors to indicate the departments where they should be used.

E. Hydrosetting

1. Process Description

The hydroset process consists of the reaction between lead and sulfuric acid and normally takes place over a period of 48 to 72 hours. The method of hydroset varies considerably between battery plants, ranging from placing the pasted plate racks in the work room to placing the racks within a temperature and humidity controlled room or chamber.

NOTE: The operations from pasting offbearer to battery rework involve work-station-to-pallet or pallet-to-work-station plate handling. The sources of exposure and recommended engineering controls and work practices are essentially the same for all of the following operations; pasting offbearer, parting, enveloping and wrapping, stacking, group dropping, and battery repair or rework. Care must be taken not to design in excess exhaust ventilation since it may cause reentrainment of settled lead dust from adjacent racks or work areas across the breathing zone to the ventilated work station.

2. Sources of Exposure

a. Material handling.

b. Positioning pallets in an area where drafts or thermals cause reentrainment.

c. Covering with burlap.

3. Work Practices

a. Do not cover with burlap.

b. Position away from cross drafts or thermals.

c. Vacuum racks and edges of plates and panels to prevent dried lead bearing dust from being reentrained.

F. Parting, Hand and Machine

1. Process Description

Grids are commonly produced and pasted as pairs and called pasted plates or panels. They must then be separated before the battery can be built. This plate breaking or parting may be performed manually, by saw, or by a parting machine. It can be done after the flash drying, after curing but before plate burning, or following plate formation process (forming, washing, drying) in the case of dry-charge battery manufacture.

2. Primary Sources of Exposure

a. Dry plate handling or moving plates in and out of work station.

b. Dried oxide on equipment, racks, and floors. This is especially critical for dry charge batteries since formation and curing in the oven have occurred at this point and the plates are very dry.

c. Buffing wheels on some parting machines and parting with a saw imparts a throw velocity to particulate which may overcome capture velocity of enclosures or local exhaust ventilation.

d. Cleaning machine jam-ups.

3. Secondary Sources of Exposure

a. Dirty clothing due to leaning up against work station or breaking plates near body.

b. Improper disposal of defective plates.

c. Improper emptying of cleanout trays.

d. Leaking tamping boxes which contribute to settle dust on the floor.

4. Engineering Controls

a. Exhaust ventilated work station; down draft or slot hood with a grating or perforated plate tamping stand. Provide an opening in tamping stand or raised positions so that lugs will not be impacted.

b. Exhaust ventilated scrap barrel.

c. Vacuum drop at work station (preferably within reach of operator so it will be used).

d. Retrofit buffing wheels on parting machines with stationary brushes if possible. Enclose ends of machine to prevent particles from being thrown out of machine.

e. Enclose saw parting operation as much as possible. For dry charge batteries this is especially important since the plates are very dry and static charges may contribute to operator exposure. A radial saw with local exhaust ventilation may be used to replace band saws normally used. If band saw is used, plates may be clamped to a tilt plate fitted with a long handle so the operator can stand to the side of the hood opening to cut the plates.

f. Supplied-air island may be required.

g. Guide bar (belly bar) to prevent operator from leaning up against equipment. Design to prevent back injury.

h. See through glass or plastic plate at tamping stand or breaking station.

i. Exhaust ventilate rack and provide a rotating base on which pallets of plates are placed. Instead of reaching over contaminated pallets to pick up plates, the rack can be rotated 180 degrees so that the plates are closer to operator.

j. Racks should be located close to work station to prevent working with plates outside of ventilated areas.

5. Work Practices

a. Make sure ventilation is working properly. Prevent cross drafts.

b. Vacuum work station and adjacent areas to prevent accumulation of oxide dust.

c. Prevent banging plates excessively during manual plate breaking. Don't break plates on a metal plate or a solid board. Handle plates only with the hands, don't lean them against the stomach. Wear aprons to prevent contamination of clothing.

d. Dust suppression techniques should be used on floors around work areas. These techniques include keeping floors wet, using sweeping compounds or vacuuming.

e. Dispose of defective plates properly. Place, don't throw, them into an exhaust scrap barrel. Cover drums with a plastic bag before they are removed from the area.

f. Make sure plate trays are clean. Vacuum the tops to avoid contaminating the next person who uses them.

g. Vacuum clean out trays, do not dump them into barrels.

h. Keep hood openings enclosed to the greatest extent possible and keep access doors closed. This is especially true by the lug brushing unit. Keeping open areas to a minimum will maximize the exhaust ventilation's effectiveness.

G. Enveloping and Wrapping

1. Process Description

Enveloping consists of placing a plate (usually a positive plate) within a porous membrane. The membrane is folded over the bottom of the plate and sealed by pressure, heat, or ultrasonic means on two sides, usually on an automatic machine. Industrial battery plates are usually hand wrapped.

2. Main Sources of Exposure

a. Improper handling of plates at the feed and discharge ends of enveloping machines, airborne oxide formed by abrasion, and the bellows effect when handling envelopes. Tamping the plates at unventilated areas such as the rack to even off the sides creates a puff of dust.

b. Dirty equipment and dust accumulations on racks and floors.

3. Secondary Sources of Exposure

a. Improper handling of scrap plates.

b. Contaminating clothing by leaning against equipment.

4. Engineering Controls

a. Down draft or slot ventilation at work station.

b. Machines that use shuttle plates for moving plates have higher airborne levels due to abrasion and must have local exhaust ventilation at the shuttle plate.

c. Exhaust ventilated scrap barrel.

d. Central vacuum drop. For battery plants with long line runs, the central vacuum system may need to be designed with drop out points so that heavy particulate can be collected to prevent plugging lines.

e. Exhaust rack and provide a rotating base on which pallets of plates are placed. Instead of reaching over contaminated pallets to pick up plates, the rack can be rotated 180 degrees so that the plates are closer.

- f. Supplied-air islands over operator's work station.
- g. Provide a grating or perforated plate tamping stand.

5. Work Practices

- a. Make sure ventilation is working properly. Prevent cross drafts.
- b. Vacuum work station and adjacent areas to prevent accumulation of oxide dust. Vacuum off each layer of plates before using.
- c. Tamp plates carefully over ventilated work station, banging them around will create excessive dust. Keep open ends of envelops away from your face. Handle groups only with the hands, don't lean them against the stomach. Provide aprons to prevent contamination of clothing.
- d. Dust suppression techniques should be used on floors around work areas. These techniques include keeping floors wet, using sweeping compounds or vacuuming.
- e. Dispose of defective plates properly. Place, don't throw, them into a ventilated scrap barrel. Cover drums with a plastic bag before they are removed from the area.
- f. Make sure plate trays are clean. Vacuum the tops to avoid contaminating the next person who uses them.
- g. Vacuum clean out trays, do not dump them into barrels.
- h. Keep all doors, windows and other openings sealed and closed on the enveloping machine. Keeping open areas to a minimum will maximize the exhaust ventilation's effectiveness.

H. Stacking

1. Process Description

After curing, the plates are stacked either by hand or machine so that positive and negative plates alternate with an insulating separator in between. If an enveloper is used, no separator is required at stacking. Hand stacking is frequently conducted at stations in which teams of workers both hand stack and group burn. In other plants, hand stacking is separated from the burning station.

2. Major Sources of Exposure

a. Improper handling of plates at the feed and discharge ends of stacking machines, airborne oxide formed by abrasion, and the bellows effect when handling unsealed envelopes. With industrial batteries, tamping the plates at the rack to even off the sides creates a puff of dust.

b. Dirty equipment and dust accumulations on racks and floors.

c. Clearing of jam-ups of machine stacking equipment.

3. Secondary Sources of Exposure

a. Improper handling of scrap plates.

b. Contaminating clothing by leaning against equipment.

c. Improper emptying of cleanout trays.

d. Not closing hinged panels on stacking machines.

4. Engineering Controls

a. Down draft or slot ventilation at work station.

b. Exhaust scrap barrel.

c. Central vacuum system. For industrial batteries, the central vacuum system may need particulate drop out points so that large particles will drop out and not plug lines.

d. Exhaust ventilate rack.

e. Provide a rotating base on which pallets of plates are placed. Instead of reaching over contaminated pallets to pick up plates, the rack can be rotated 180 degrees so that the plates are closer.

f. Machines that use shuttle plate for moving plates have higher airborne levels due to abrasion and must have local exhaust ventilation at shuttle plate.

g. Supplied-air island over operator's work station.

h. Provide a grating or perforated plate tamping stand.

i. Provide a plastic or glass see through plate between the stacker's breathing zone and the plates.

j. Keep floor continuously wet to prevent dust dispersion. Provide rubber mats or grating walking surfaces. Care must be taken with dry charge batteries since water can ruin plates.

5. Work Practices

a. Make sure ventilation is working properly. Prevent cross drafts.

b. Vacuum work station and adjacent areas to prevent accumulation of oxide dust. Vacuum off each row of plates before using.

c. Tamp plates carefully over ventilated work station, banging them around will create excessive dust. Handle groups only with the hands, don't lean them against the stomach. Provide aprons to prevent contamination of clothing.

d. Try to maximize the distance between the operator's breathing zone and the plates. Don't stack the assembled groups more than 2 or 3 high for the burning machine operator.

e. Dispose of defective plates properly. Place, don't throw, them into a ventilated scrap barrel. Cover drums with a plastic bag before they are removed from the area.

f. Dust suppression techniques should be used on floors around work areas. These techniques include keeping floors wet, using sweeping compounds or vacuuming.

g. Make sure plate trays are clean. Vacuum the tops to avoid contaminating the next person who uses them.

h. Vacuum clean out trays do not dump them into barrels.

i. Keep openings enclosed to extent possible and keep access doors closed. Keeping everything closed will maximize the exhaust.

I. Group Burning

1. Process Description

After the plates have been stacked they are joined with small connecting parts and burned together to form cell elements or groups. This operation is conducted manually at a burning station or by using an automatic cast-on-strap (COS) machine. The burning station consists of a fixture into which elements are placed (dropped) and which holds the plates in the elements while the respective positive and negative plates are joined. Small parts, which will become intercell connectors or posts, are placed in the fixture and bonding is achieved by melting lead bars with a hand held torch.

There are three primary COS machines in use: Farmer, Dynacast and MAC. The Farmer COS is a 4-step operation. The first step is to place the groups in a rack; next the rack turns 90 degrees where a wire brush cleans and roughs the lugs; the rack rotates another 90 degrees and lugs are submersed in molten lead soldering the groups together and applying a strap; finally, the rack rotates another 90 degrees and it is inverted. The groups are removed, tamped, and inserted into battery containers located on a conveyor.

The Dynacast and MAC COS go through the same basic steps as the Farmer. The equipment is set up in a straight line instead of rotating 90 degrees for each step of the process.

2. Primary Sources of Exposure

a. Automatic COS Machines.

(1) Dry plate handling or moving plates in and out of work station.

(2) Dust accumulations on racks, equipment and floors. Tamping in a nonventilated area.

(3) Group dropping.

(4) Lug brushing.

b. Manual Group Burning.

(1) Lead fume generated during burning with torches.

(2) Handling groups in and out of work station and burning box.

(3) Cross contamination at team stack and burn stations.

(4) Exhaust ports of pneumatic systems causing settled dust to become airborne.

3. Secondary Sources of Exposure

a. Drossing and feeding lead pot.

b. Group repair operations.

c. Cleaning molds using compressed air.

d. Adjusting and repairing equipment and change overs.

4. Engineering Controls

a. Automatic COS Machines.

(1) Down draft or slot ventilation at the feed end.

(2) Enclose the machine and lead pot in a ventilated room. Provide access door for maintenance and a small port for drossing and loading lead pot.

(3) Provide local exhaust ventilation at the melting pot, mold heating section, dross pot, lug brush, and the casing areas. Ventilation includes a slot hood at the lug brush and casing station and an enclosure around the melting pot and dross pot. Because lead particulate is generated with an initial velocity at the lug brush, the slot is positioned in the direction of generation, not behind the brush. Also, the semi-enclosure around the brush should be exhausted to help collect particulate entrained in the brush.

(4) Supplied-air island above the operator's work station.

b. Manual Group Burning

(1) Down draft or slot hood at work station for tamping. A rotating rack may be provided so operator does not have to lean over contaminated racks to reach groups.

(2) Exhaust burning box for both fume and dust. Use slot ventilation at burning and group dropping stations. If there is a fume problem, use of a smaller torch tip may lower exposure.

(3) For team stack and burn operations, provide an enclosed lazy susan for holding the stacked groups. A plastic sheet can be placed at the stacking side to control the height of the stacks and prevent cross drafts.

(4) Local exhaust ventilation around torch head. This can be provided with a portable welders exhaust hood with HEPA filters or a movable exhaust hood on a monorail or other configuration.

(5) Exhausts of pneumatic clamping systems can be piped away from work station for venting.

(6) Supplied-air island above the operator's work station.

5. Work Practices

a. Make sure ventilation is working properly. Prevent cross drafts.

b. Avoid setting torches at too high a temperature since this will increase the amount of fume generated. Substitute cooler flames such as air-propane or air-MAP gas for air-acetylene. To overcome the increase in time required for burning, the torch heads may be changed.

c. Vacuum work station and adjacent areas to prevent accumulation of oxide dust. Vacuum off each row of plates or groups before using.

d. Tamp plates over ventilated work station, banging them around will create excessive dust. Provide a grating or perforated plate tamping stand. When dropping groups into container, place opening toward exhaust ventilation not away from ventilation.

e. Handle groups only with the hands, don't lean them against the stomach, chest or chin. Provide aprons to prevent contamination of clothing.

f. Try to maximize the distance between the operator's breathing zone and the plates. If practical, stand on a platform to further increase the distance from the plates. Don't stack the assembled groups more than 2 or 3 high for the burning machine operator. Provide a plastic or glass see through plate between the stacker's breathing zone and the plates.

g. Keep openings to a minimum and keep access doors closed. Care must be taken with dry charge batteries since water can ruin plates. Keeping openings to a minimum will maximize the exhaust ventilation's effectiveness.

h. Dispose of defective plates properly. Place, don't throw, them into a ventilated scrap barrel. Cover drums with a plastic bag before they are removed from the area.

i. Make sure plate trays are clean. Vacuum the tops to avoid contaminating the next person who uses them.

j. Vacuum clean out trays do not dump them into barrels. Vacuum, do not use compressed air, when cleaning molds.

k. Dust suppression techniques should be used on floors around work areas. These techniques include keeping floors wet, using sweeping compounds or vacuuming. Provide rubbers or gratings for walking surfaces. If elevated platforms are used, keep height at a minimum to prevent lower back stress and other related ergonomics problems.

J. Intercell Welding and Post Burning

1. Process Description

After the groups have been placed in a battery container, the straps on adjacent elements are fused together using a torch or a high current power source. The units are then tested and the tops and terminal posts are attached. Post or terminal burning involves using lead, a torch, and a mold. Lead is either dipped from a molten bath or else is applied by melting lead bars into a mold cavity. The mold cavity is created by using a metal cover plate, called a burning dam, which is placed on top of the battery prior to torching.

2. Major Sources of Exposure

a. Lead fume from the torch.

b. Manual handling of burning jigs or dams contaminated with metal oxides.

3. Secondary Sources of Exposure

a. Repair of defective batteries.

b. Exhausting too much air pulls contaminated air from other areas.

c. Pointing torch flame into battery container blows out particulate.

4. Engineering Controls

a. Local exhaust ventilation around torch. This can be provided with a portable welders exhaust hood with HEPA filters or a movable exhaust hood on a monorail or other configuration.

b. Slot ventilation at work stations close to where burning is performed.

c. Canopy or slot hoods if lead pots are used.

d. A down draft or slot hood ventilated work station if battery repair is performed.

e. A plastic or glass see through guard between the operator's breathing zone and the conveyor carrying batteries.

f. Supplied-air island above work station.

g. Keep torch hose lengths to a minimum to prevent employee from working outside the hood area.

h. Substitute air-propane or air-MAP gas for air-acetylene flames to keep burning temperatures low.

5. Work Practices

a. Check ventilation is working properly.

b. Battery repair should be performed at a ventilated work station. Any oxide spills should be vacuumed up immediately.

K. Formation

1. Process Description

   a. In some operations the battery plates or panels are formed (charged) in tanks rather than in the case. Tacking is accomplished with a small torch where a lead bar is welded to the lugs of the panel or group.

   b. Once the panels or plates have been removed from the charging tanks, they are dried. Positive plates are normally dried in recirculating hot air ovens. To reduce handling of the positive plates, the same rack that the pullers use for the positive plates is used in the positive drying oven.

   c. Negative plates present a different problem. If the plates are dried in air, they will oxidize and thereby discharge. Consequently, special drying ovens are used for negative plates. Negative drying ovens usually use inert gas, such as carbon dioxide or steam, or reduce the amount of available oxygen by drawing a vacuum on the oven. Typically, it is necessary to transfer plates to special drying racks at the oven.

2. Major Sources of Exposure

   a. Tacking or connecting the panels.

   b. Manual handling of the dry plates. Moving plates in and out of acid tanks and drying ovens and racks.

   c. Sticking or placing the panel or groups in the acid tanks.

   d. Cleaning panel lugs by brushing prior to welding.

3. Engineering Controls

   a. Local exhaust ventilation on torch.

   b. Cover tanks and ventilate specific tank when you are tacking it. Leave all others closed.

   c. Use patented process called "tackless formation".

4. Work Practices

   a. Check that ventilation is working properly.

b. Wet plates down before they are put into the system. If hoses do not adequately wet plates, showers or dip tanks are necessary.

c. Use fork lifts instead of manual handling to move groups in and out of ovens.

d. Vacuum racks and ovens before moving groups.

e. Keep floors around ovens and rack storage clean.

L. Battery Repair

1. Process Description

Defective batteries are repaired and salvaged. The plate groups are tested and reused when possible. Groups are removed by sawing or cutting the covers of the battery, breaking or burning the intercell connectors and removing the groups.

2. Primary Sources of Exposure

a. Improper handling of battery while removing plates: (1) spilling oxide out of container, (2) banging dry plates or containers, and (3) sawing container in an unventilated area.

b. Generation of fume while using torch for disassembly.

c. Bellows effect caused by moving groups in and out of containers.

d. Storage of spare parts.

3. Engineering Controls

a. Slot and/or down draft ventilation at work station.

b. Vacuum drop at work station.

c. Local exhaust ventilation on torch.

d. Prove ventilated areas for storage of tools, plates and supplies.

e. Use air-propane or air-MAP gas instead of air-acetylene flame for torch.

4. Work Practices

a. Make sure ventilation is working properly.

b. Keep area vacuumed and cleanup all oxide spills immediately.

c. Dispose of elements into a ventilated scrap barrel. Place, do not throw, elements into barrel. Cover barrel with plastic before moving.

d. Open container and disassemble in ventilated area only.

e. Materials should not be stored on active work surfaces so as to interfere with ventilation.

M. Reclaim

1. Process Description

Reclaim operations involve recycling scrap grids, plates, and straps. Two different processes are used; dry and wet reclaim. In dry reclaim the scrap material is remelted in a lead pot, dross is removed, and lead ingots poured. Wet reclaim operations involve a preliminary separation of the paste from the plates and concentrating the paste before reprocessing the materials by remelting and pouring ingots. Wet lead should never be added to a heated lead pot.

2. Primary Sources of Exposure

a. Dry Reclaim.

  (1) Barrel dumping.

  (2) Handling of scrap materials.

  (3) Transport of material to the reclaim area.

  (4) Oxide spills, contaminated equipment and barrels.

  (5) Lead pot emissions during dumping of scrap and drossing.

  (6) Material handling of dross.

  (7) Pig pouring operations.

b. Wet Reclaim.

  (1) Splashes of oxide on floors and equipment which dry up and becomes airborne.

  (2) Handling of scrap materials.

  (3) Transport of material to the reclaim area.

  (4) Paste spills and contaminated equipment and barrels.

  (5) Lead pot emissions during dumping of dry scrap and drossing.

(6) Material handling of dross.

(7) Pig pouring operation.

3. Engineering Controls

a. Dry Reclaim.

(1) Replace manual handling with mechanical material handling: (a) replace manual loading of melting pot with ventilated conveying system, ventilated barrel dumper, or front end loader; (b) replace manual drossing with automatic drossing.

(2) Exhaust melting pot and drossing operation. Note: because dry material is handled and high levels of dross may be obtained, increase ventilation rates will be required over those required for other melt pots in casting or COS operations.

(3) Exhaust ingot casting operation.

(4) Isolate reclaim operation from rest of plant operations.

(5) Provide exhaust ventilated scrap barrels at work stations.

b. Wet Reclaim.

(1) Replace manual handling with mechanical material handling: (a) replace manual loading of melting pot with ventilated conveying system, ventilated barrel dumper, or front end loader; (b) replace manual drossing with automatic drossing.

(2) Exhaust melting pot and drossing operation. Note: because dry material is handled and high levels of dross may be obtained, increase ventilation rates will be required over those required for other melt pots in casting or COS operations.

(3) Exhaust all transfer points and reclaim processes: manual transfer to conveyor, storage hopper, barrel dumper. Use long handled tools when possible.

(4) Cover and exhaust all moving equipment that comes in contact with wet or dry paste.

(5) Isolate reclaim operation from rest of plant operations. Provide screening or curtains to contain splatter.

(6) Exhaust ingot casting operation.

(7) Provide ventilated scrap barrels at work stations.

4. Work Practices

a. Dry Reclaim.

(1) Make sure ventilation is working properly.

(2) Cover all containers of scrap material while being transferred or handled.

(3) Caution must be taken to make sure that all scrap has been dried before dumping into melt pot. Drosses formed from melting mixed alloys containing Ca, Al, As, and Sb may form hazardous gases such as arsine and stibine if the drosses become wet.

(4) Vacuum any spills immediately and keep the area clean.

(5) Dust suppression techniques should be used on floors around work areas. These techniques include keeping floors wet, using sweeping compounds or vacuuming. Water wet down may be used around the area but keep water away from the melt pot.

(6) Provide additional coveralls, lab coats, or aprons and a face shield to prevent contamination of employee.

(7) Clean all drums after dumping. Wash down floors often. Don't let the floor surface become dry.

(8) Avoid splashing lead when pouring pigs. If a torch is used in cleanup of splashed lead, use local exhaust ventilation to avoid breathing fumes.

b. Wet Reclaim.

(1) Make sure ventilation is working properly.

(2) Cover on all containers of scrap material while being transferred, handled, or stored.

(3) Caution must be taken to make sure that all scrap has been dried before dumping into melt pot. Drosses formed from melting mixed alloys containing Ca, Al, As, and Sb may form hazardous gases such as arsine and stibine if the drosses become wet.

(4) Vacuum any spills immediately and keep equipment and area washed clean at all times. Keep water away from melt pot.

(5) Dust suppression techniques should be used on floors around work areas. These techniques include keeping floors wet, using sweeping compounds or vacuuming. Water wet down may be used around the area but keep water away from the melt pot.

(6) Provide additional coveralls, lab coats, or aprons and a face shield prevent contamination of employee.

(7) Perform all work carefully to minimize splashing oxide on clothing, equipment, walls, etc.

(8) Clean all drums after dumping. Wash down floors often. Don't let the floor surface become dry.

(9) Avoid splashing lead when pouring pigs. If a torch is used in cleanup of splashed lead, use local exhaust ventilation to avoid breathing fumes.

VII. OTHER PROCEDURES

A. Material Handling and Lead Exposure

Material handling is a major potential source of lead exposure in battery manufacturing plants. Recognize that most plants are "job shops" making many different products "to order" and that, as a result, many mechanization techniques are not applicable. (An automotive battery plant, for instance, may manufacture 200-250 batteries from 30-60 different plate types.) An overall evaluation of material flow through plant should be performed to reduce repetitive material handling.

1. The Source

The primary source of lead exposure in a battery factory is from lead compounds such as lead oxides. Very few operations have the potential for emitting measurable lead fume and these are not under discussion here.

2. Lead Oxides

Lead oxide may be manufactured or purchased.

The two primary methods of handling lead oxide are from drum storage and/or tank storage.

All lead oxide storage systems have the potential for leaking, particularly around seals and sampling points. The first step in controlling lead oxide in a plant is a reliable written preventative maintenance program to insure the integrity of the system.

Manufactured oxides are produced in one to two general types of oxide mills. The "Barton-type" mill melts lead which then flows into a mill where oxygen is added and the material is mixed, breaking down into smaller and smaller particles. The "Ball mill-type" feeds lead slugs (as large as 65 pound pigs) into the throat of a rotating mill, adds (air) oxygen and concusion breaks the lead into smaller and smaller particles. Heat from the friction of tumbling lead and oxidation enhances the process.

Purchased oxide is brought to the plant either in drums or in "pod" cars which put the material into storage by pneumatic conveying ("blowing") it into storage tanks. The type of manufacturing technique is incidental to lead exposure, but the method of storage and dispensing the oxide may be critical to good lead control.

3. Paste Mixing

Lead oxides are moved to the paste mixer in two different manners: (1) drum handling or (2) oxide conveyor (either a screw conveyor, pneumatically, or enclosed gravity chute).

The drum handling method involves moving oxide drums to a "drum dumping device" and removing the cover from the drum, which is then mechanically lifted and inverted to place the oxide in the paste mixer. This process has the potential for releasing substantial lead into the air and requires strict control.

a. Vacuum any dust from drum surface before moving to the "barrel dumper".

b. Place the drum inside the covered dump mechanism (which must be under negative pressure) before removing the cover. Remove cover slowly to prevent oxide from overcoming the hood ventilation due to the bellows effect.

c. Close the door through which the barrel entered before activating the lift mechanism. (The door must seal tightly.)

d. The entire lift conveyor requires a written preventative maintenance program to prevent leaks.

Oxide conveying systems must be well maintained to prevent leakage. Shut off gates should be provided on both sides of rotary air locks and star feeders for maintenance.

Dumping oxide into the paste mixer, whether from drum storage or tank storage (bulk storage) requires that:

a. The mixer must be under enough negative pressure to prevent escape when the oxide is dropped into the mixer.

b. The door(s) must seal tightly to prevent escape of oxide.

4. General Material Handling Exposure

The oxide is mixed with water, sulfuric acid and other ingredients to form a "paste", which is then pressed into a grid frame made of cast or expanded lead. Dust exposure from dried paste may take place at any or all successive operations. The amount of subsequent exposure depends primarily upon how the material is handled.

5. Material Handling Vehicles

Much material moves between operations with the aid of mechanical material handling equipment. Problems may result from the truck itself, as well as from the method and care taken in actual transport.

Note that any material handling vehicle moving over a dusty floor will cause some of that dust to become airborne or tracked into other areas. Housekeeping programs should address this issue. Also, material handling vehicle propelled by internal combustion engines or having cooling fans may cause dust to become airborne.

The load being carried is a potential source of lead exposure. Any material in a battery plant will have some lead dust on the surface that may become airborne from vibration or air movement. General rules for truckers should include:

a. Keep speed down. The faster a material handling vehicle moves, more air moves through the load, picking up dust. Note this importance, not only from the standpoint of general plant exposure, but that the dust may overexpose the driver.

b. Any skid, pallet, tub or other conveyance which holds or has held plates, must be vacuumed before movement.

c. Loads should be raised and lowered gently to prevent jarring which would produce lead dust.

d. The conveyance system (skids, pallets, etc.) should be reviewed to make certain that material or dust created on or in the conveyance cannot be dropped on the floor where material handling vehicle or foot traffic could result in airborne exposure.

6. Conveyors

Lead material moved on conveyors has resulted in less potential exposure than movement by material handling vehicle. Care must be taken to avoid vibration caused by bumping and banging which could result in excess exposure.

7. Manual Material Handling

Manual material handling is the source of most lead exposure in most battery plants. The manufacturing process requires substantial hand labor and, in some plants, the plates may be handled up to 20 times after being pasted before they are sealed in the battery.

Much of the information which follows will also relate to work habits (discussed elsewhere).

1. "Pallet-to-work-station" or "work-station-to-pallet" handling may occur at many locations in the plant. General rules should include:
    a. Vacuum each layer on a skid or pallet before progressing to the next. Vacuum drops must be near the operator and properly tooled and maintained or they won't be used.
    b. Lift and set down material carefully. No dropping, or banging.
    c. All work done to material must, as nearly as possible, be done under ventilation.
    d. Vacuum empty containers or pallets before they leave the work station.
2. Scrap handling can be a major source of exposure:
    a. Place scrap carefully in designated containers (preferably under ventilation). Don't dump, drop, throw or disturb material more than is absolutely necessary.
    b. Scrap containers should be covered when not in use.
    c. Scrap containers where possible should be attached or located so that material will not have to leave the work station ventilation for disposal.
    d. Containers of scrap should not be moved until they have been covered.
    e. Don't overfill scrap containers.
3. Work inside the ventilated enclosure. Don't scrape material over the edge on entry or removal.

4. Cleaning of equipment is part of scrap removal. Equipment must be vacuumed frequently and catch-drawers emptied, preferably by vacuuming.

5. Emptying catch-drawers into other containers can cause substantial lead dust to become airborne. If it is necessary to empty, as opposed to vacuuming, the procedure should be accomplished only under ventilation.

6. Baghouses, vacuum systems and related ductwork are part of the scrap removal system. Systems which do not function properly or are not properly emptied cannot move enough lead dust from the intended location. Frequent velocity checks are required.

7. Baghouses and vacuum systems usually empty into barrels. These "dump" stations must be tightly sealed. Removal of barrels should take place in accordance with equipment operation procedures. Tops should be placed on barrels before they are moved. Barrels should never be overfilled.

In summary, the movement of material cannot be separated from many other control procedures, including equipment maintenance and use and good work habits. In practice the material handling portions of lead control must be integrated into the job description for all work being done at all work stations.

Many have experienced significant exposure reduction through judicious review and implementation of material handling training and regulations for all employees.

B. Work Practices/Housekeeping

Work practice control is defined as a specified method for doing a particular job so that exposure to lead dust, fume or mist is minimized and lowered compared to other methods for doing the same job. In order to reduce employee lead exposure to the lowest extent feasible, employers should investigate and implement appropriate work practices.

The employer/employee should develop a written job analysis which includes proper safety and health procedures for each job in the plant. This should be included in the compliance plan. The job safety and health analysis defines the equipment, material used, crew size, job responsibilities, housekeeping responsibilities and how the job can best be performed to minimize health and safety exposures.

Good housekeeping practices are also essential in minimizing employee exposure to lead to the lowest extent feasible. The OSHA Lead Standard addresses the following housekeeping requirements:

> 29 CFR 1910.1025(h) Housekeeping--(1) Surfaces. All surfaces shall be maintained as free as practicable of accumulations of lead. (2) Cleaning floors. (i) Floors and other surfaces where lead accumulates may not be cleaned by the use of compressed air. (ii) Shoveling, dry or wet sweeping, and brushing may be used only where vacuuming or other equally effective methods have been tried and found not to be effective. (3) Vacuuming. Where vacuuming methods are selected, the vacuums shall be used and emptied in a manner which minimizes the re-entry of lead into the workplace.

There are several methods of effectively complying with the requirements of this portion of the standard.

1. Vacuum

    a. Heavy Duty Central System-with optional clean out or material drop out points in the pipe system.

    b. Portable - (A portable low volume machine will not do the job adequately.) Note that exhaust air from portable vacuum units may contain lead dust and should not be vented to the room environment unless HEPA filters are used. Also, care must be taken that the vacuum exhaust does not disturb lead bearing dust on nearby surfaces.

2. Water Wash-Down

The conventional water hose has been widely used in the industry for a number of years. A new device has been developed using a high pressure water jet and is currently being used in areas where considerable lead dust is settling on support structures and equipment. The most widely used method is to use a water hose, collect water wash down material, treat and recycle that treated water to the wash-down system. Some battery facilities have installed a constant drip system to maintain a constant film of water around the pasting line. Others have bermed the area and keep the area constantly wet by spraying with a fine mist. Care should be taken when working near energized electrical sources to prevent employee contact with water.

3. Vacuum Scrubber or Sweeper

Vacuum scrubber or sweeper machines may be small, walk-behind models or intermediate-size riding models.

Examples are shown in Figures 6 through 8. These sweepers typically have two sets of brushes: a circular side brush on the front and a cylindrical extension brush across the body of the machine. The side brush loosens dirt at the edge of one side of the sweeper and moves it into the path of the extension brush for pick-up. The extension brush rotates to throw debris into the collection hopper. Rubber skirting is used to enclose the extension brush as much as possible. The scrubber or sweeper's vacuum system removes dust from the enclosure around the extension brush as well as the collection hopper. Exhaust air from the vacuum system passes through a bank of filters before discharge to the atmosphere. Sweepers or scrubbers must be designed to remove toxic materials. Side brushes, if used, must be properly ventilated.

Small walk-behind sweepers may be used in some plant areas. Most walk-behind sweepers are used inside plant areas. Larger sweepers are used in paved yard areas. Walk-behind sweepers, like the larger units, typically use a two-brush sweepers and include a scrubber attachment for wet scrubbing. Some walk-behind units operate exclusively as wet scrubbers. These models automatically apply a wetting solution (which may contain surfactants), scrub with brushes, and pick up the cleaning solution as the operator maneuvers the machine over the area to be cleaned.

Vehicle exhaust, cooling system fans, and vacuum system discharge can resuspend settled dust on interior building surfaces. Care must be taken that lead dust does not enter the air during cleaning or emptying the sweeper. The disposal of wet floor washings must be done in accordance with federal, state, and local regulations regarding liquid wastes containing lead.

FIGURE 6

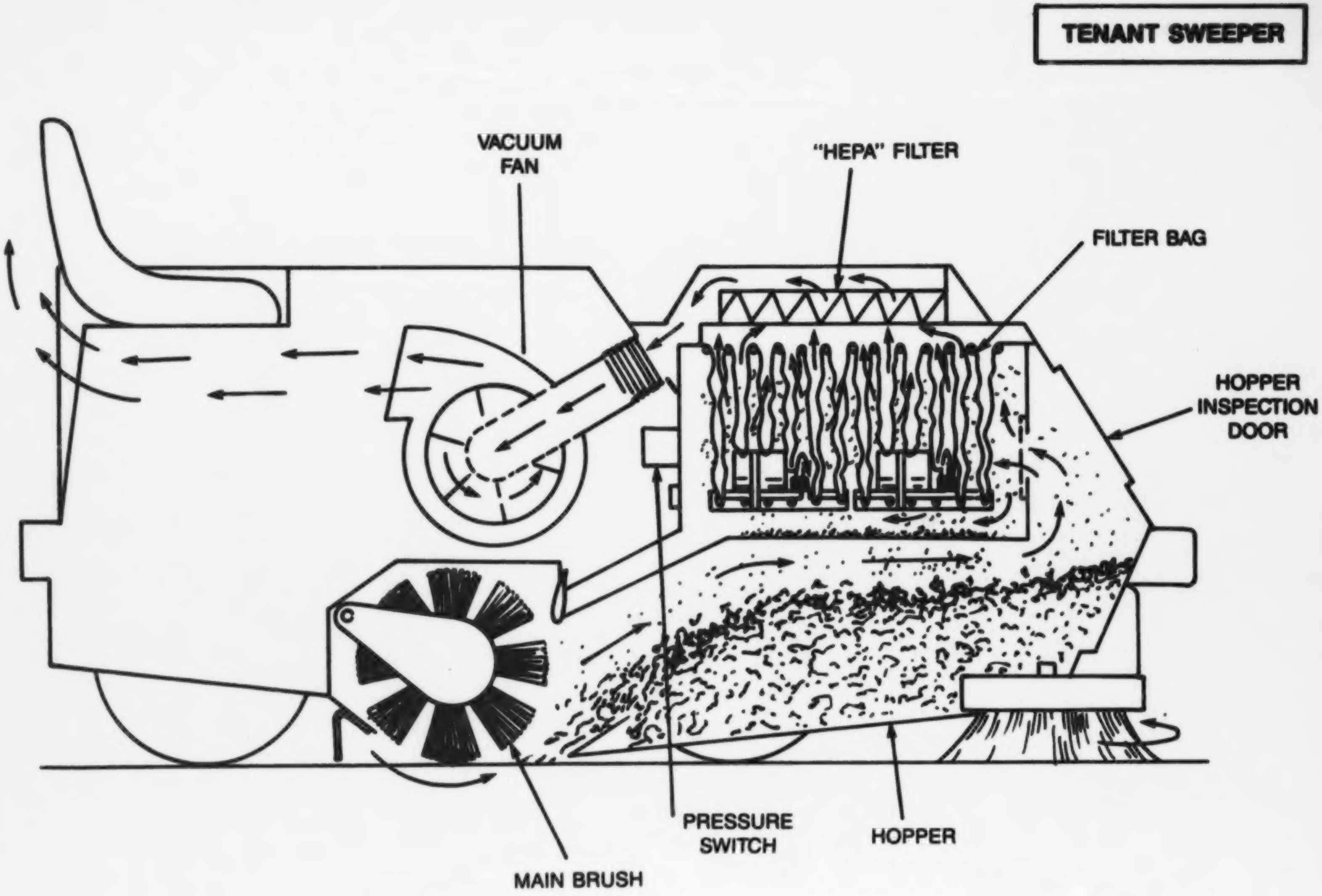

TENANT SWEEPER
VACUUM FAN
"HEPA" FILTER
FILTER BAG
HOPPER INSPECTION DOOR
PRESSURE SWITCH
HOPPER
MAIN BRUSH

FIGURE 7

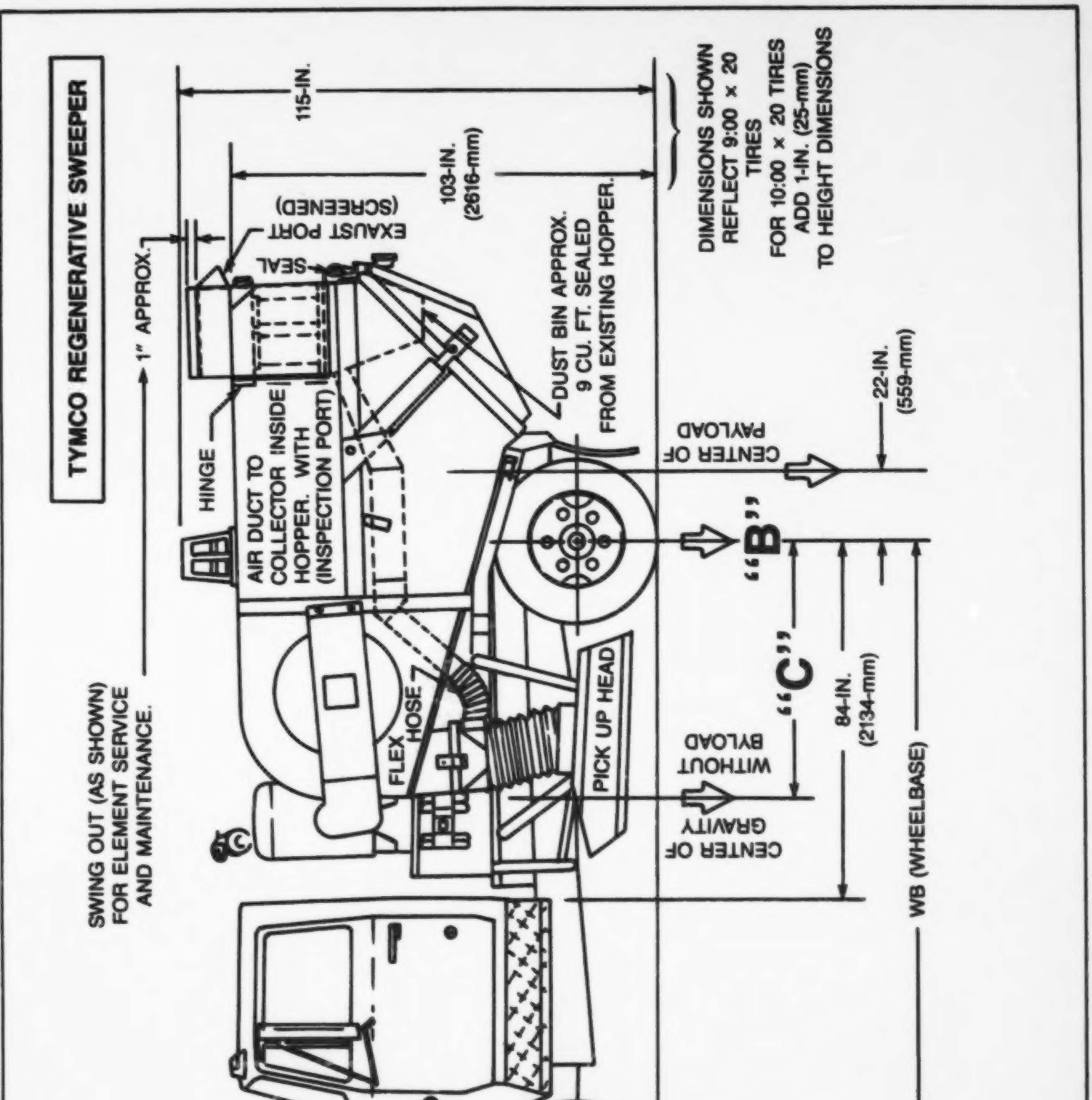
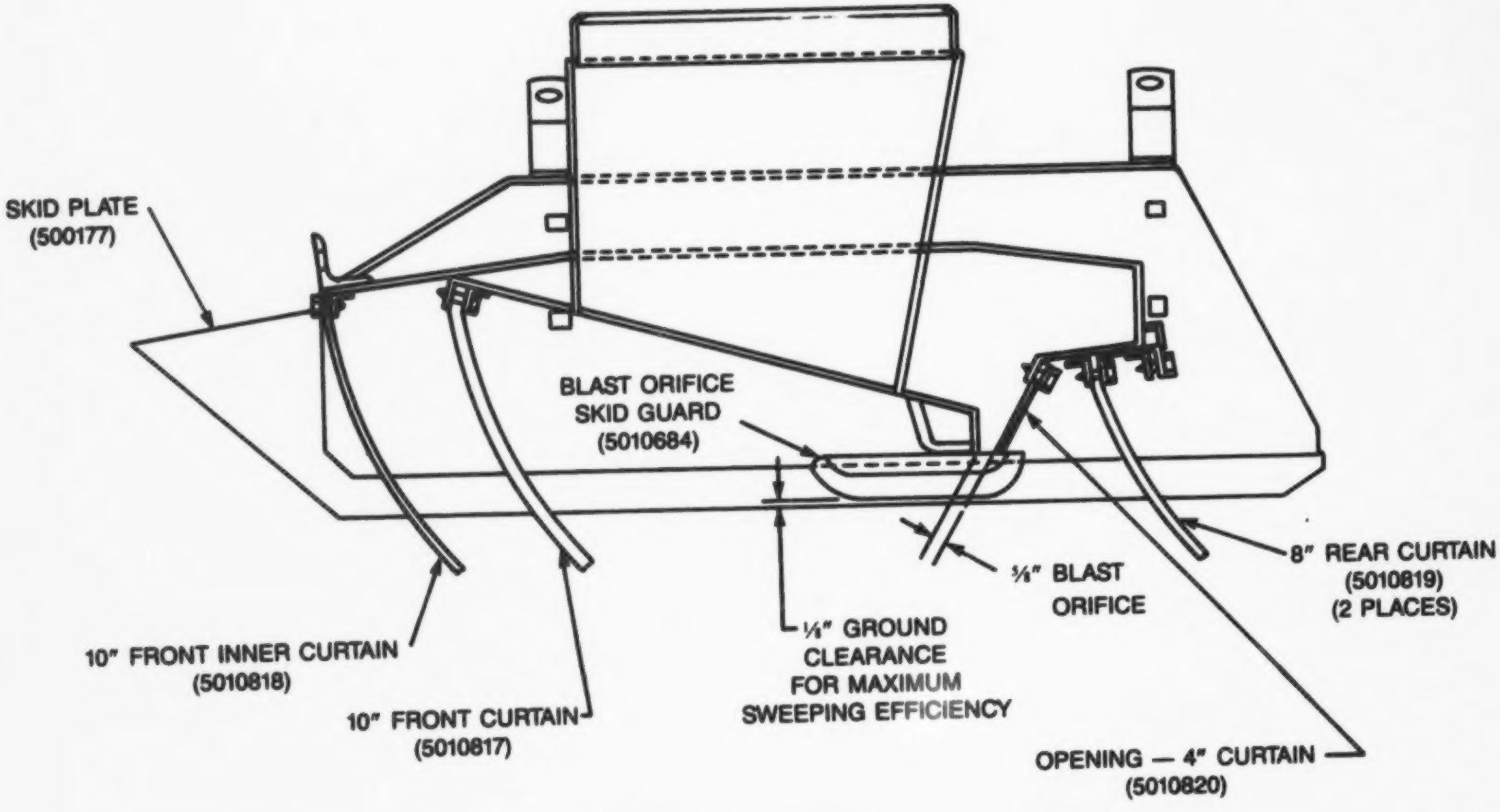

TYMCO REGENERATIVE SWEEPER
SWING OUT (AS SHOWN) FOR ELEMENT SERVICE AND MAINTENANCE.
1" APPROX.
HINGE
EXAUST PORT (SCREENED)
SEAL
AIR DUCT TO COLLECTOR INSIDE HOPPER. WITH (INSPECTION PORT)
115-IN.
103-IN. (2616-mm)
DUST BIN APPROX. 9 CU. FT. SEALED FROM EXISTING HOPPER.
DIMENSIONS SHOWN REFLECT 9:00 × 20 TIRES
FOR 10:00 × 20 TIRES ADD 1-IN. (25-mm) TO HEIGHT DIMENSIONS
FLEX HOSE
PICK UP HEAD
CENTER OF GRAVITY WITHOUT BYLOAD
CENTER OF PAYLOAD
"A"
"B"
"C"
22-IN. (559-mm)
84-IN. (2134-mm)
WB (WHEELBASE)

FIGURE 8: PICKUP HEAD CROSS SECTION


SKID PLATE
(500177)
BLAST ORIFICE
SKID GUARD
(5010684)
10" FRONT INNER CURTAIN
(5010818)
10" FRONT CURTAIN
(5010817)
¼" GROUND
CLEARANCE
FOR MAXIMUM
SWEEPING EFFICIENCY
⅜" BLAST
ORIFICE
8" REAR CURTAIN
(5010819)
(2 PLACES)
OPENING — 4" CURTAIN
(5010820)

CROSS SECTION

NOTE: SUCTION BAFFLE
(5010832) NOT SHOWN

C. Clean Air Systems

1. Supplied-Air Island (SAI)/Laminar Flow System

Supplied-Air Islands have been used to provide a zone of clean air at a work station. These units serve two main purposes: (1) they protect the worker from exposure to contaminated background air, and (2) they help propel dust produced at the work station away from the operator's breathing zone. This is especially important when work is performed away from local exhaust ventilation.

The supplied air may come from outside the plant or may be recirculated air. (Recirculated air must meet the requirements of 1910.1025(e)(5)(ii) for high efficiency filtration with a back-up filter, particulate monitor and an abort mechanism in the event of system failure.) The air flow should be at a low enough velocity so that additional airborne lead dust is not generated.

Figure 9 shows two basic types of supplied-air islands: (1) the adjustable nozzle, and (2) the fixed island. The adjustable nozzle allows the employee some flexibility in position. The fixed island allows a larger area to be protected. The adjustable nozzle is primarily used as a cooling device. However, if a company has installed all possible local exhaust and has implemented all possible work practice controls and still is above the 50 ug/M^3 PEL, then an adjustable nozzle or fixed island is less expensive and can be retrofitted more readily, especially when equipment or superstructures present a space problem. The adjustable nozzle has not gained the acceptability in the battery industry that the SAI has and has primarily been used in the lead smelting industry.

A chamber within the plenum of the SAI distributes the flow through small holes across the lower surface, Figure 10, View 1. Figure 10, View 2 shows the same system with curtains of clear plastic provided to further surround the operator and prevent contaminated air from entering the breathing zone by reentrainment or from cross drafts.

Plenum height is typically 80 inches from the floor but is often restricted by overhead clearance limits and other equipment installed in the area. The air flow is designed so that the velocity measured six inches from the center is 100-150 feet per minute. Higher velocity may stir up lead dust. SAI's are often used in conjunction with local exhaust ventilation, Figure 10, View 3. In this case the air should be balanced so that make-up air is provided equal to the amount of the exhaust air.

The temperature of the make-up air should be automatically regulated. In most climates, the fall and spring months can present highly varying temperature conditions for which it is difficult to provide properly tempered make-up air. If the make-up air temperature varies widely, workers will shut off the system and risk increased exposure. Recirculated exhaust systems should be similarly designed to automatically blend recirculated and outside air to achieve a desired temperature.

CONDITIONS SUITED TO THE APPLICATION OF A SUPPLIED-AIR ISLAND TO EXPOSURE CONTROL

CONDITION	NEED
Employee remains in stationary position	Important because the more time an employee remains in the island, the lower the TWA exposure.
A supply of fresh, clean air is available	Outside air may not require cleaning and costs will be lower. If no outside source of clean air is used, intake air should be filtered.
The air can be tempered	Employees will not remain in an environment which is either too hot or too cold. The incoming air can be tempered; or alternatively, employees must be rotated in and out of the island.

Figure 9 shows the typical expansion and contamination of the air stream from a supplied-air island. As can be seen, the larger the hood face diameter, the larger the zone of protection, and the more "safe" space is created.

2. Clean Air Station/Control Room

Use of supplied-air control rooms is an effective means of lowering employee exposures. Some of these supplied air rooms are used as control rooms for the process or a lead free environment where employees can remove their respirators. For example, controls rooms are sometimes used with Ball Mills where the operator can perform quality control testing and have a low lead environment for the majority of the day. The rooms have a positive pressure, tempered, filtered air system filtered with a HEPA filter designed to remove 99.97 percent of lead dust greater than 0.3 micron in diameter. Clean air islands and stand-by pulpits have not found much use in the battery industry although they may find application in small plants as an inexpensive alternative to laminar flow hoods.

Supplied-air control rooms and stand-by pulpits must be properly cleaned and maintained if they are to continuously maintain low ambient lead concentrations. Enclosures should be vacuumed and scrubbed with soap and water so that no lead dust is allowed to collect on flat surfaces. The structural integrity of the enclosures must remain intact and under positive pressure at all times; no holes or cracks through which lead may enter should be tolerated.

Preventive maintenance should be performed on a regularly scheduled basis. Maintenance of the ventilation systems for enclosures are particularly important. The system filter trains should not become clogged or damaged. Intake and exhaust air flow must be carefully monitored to ensure that the rooms are under positive pressure at all times.

If auxiliary equipment such as air showers or shoe cleaners are part of the control room or pulpit, this equipment should be kept in good working order. Malfunctioning equipment will not serve its intended purpose of reducing employee lead exposure. Additionally, employees may be discouraged from accessing enclosures if they must deal with malfunctioning or broken equipment.

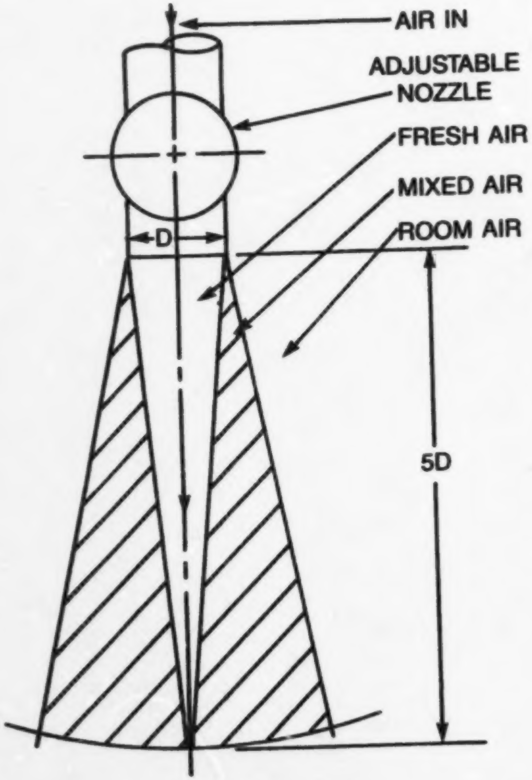
To assist battery industry management in maintaining high performance of control rooms and pulpits, a preventive maintenance checklist should be developed for individual plants based on the specific designs and operating modes of enclosures. The checklist should include schedules for:

a. Ventilation system filter replacement.
b. Replacing ventilation system hoses, clamps, and blower internal parts.
c. Replacing window and door moldings.

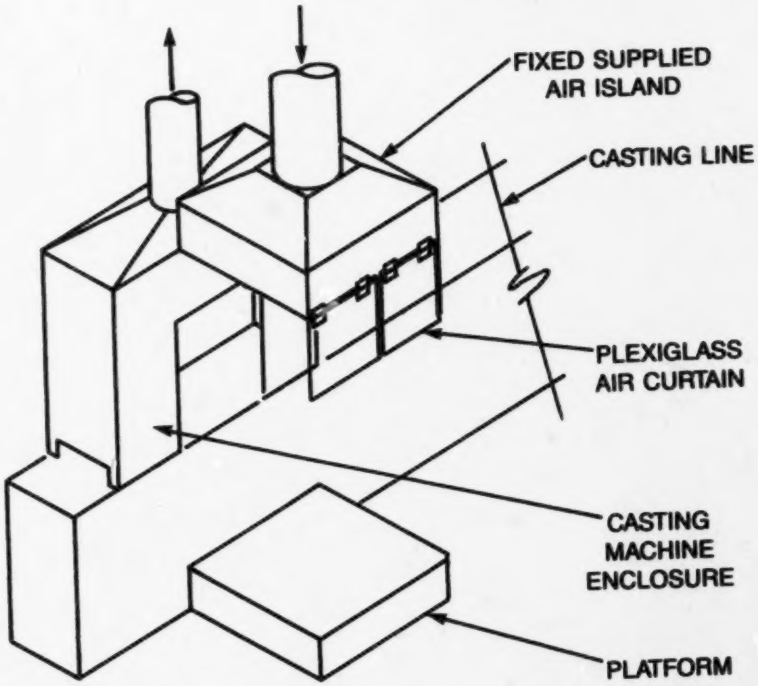
d. Checking and replacing air shower ventilation system internal parts, including automatic doors, blower, nozzles, and lighting.

FIGURE 9

SUPPLIED AIR ISLANDS — ADJUSTABLE AND FIXED TYPES


AIR IN
ADJUSTABLE NOZZLE
FRESH AIR
MIXED AIR
ROOM AIR
D
5D

ADJUSTABLE NOZZLE
SUPPLIED AIR ISLAND


FIXED SUPPLIED AIR ISLAND
CASTING LINE
PLEXIGLASS AIR CURTAIN
CASTING MACHINE ENCLOSURE
PLATFORM

APPLICATION OF A FIXED
SUPPLIED AIR ISLAND

DESIGN CHARATERISTICS

FLOW RATE: 1800 – 5000 SCFM PER STATION

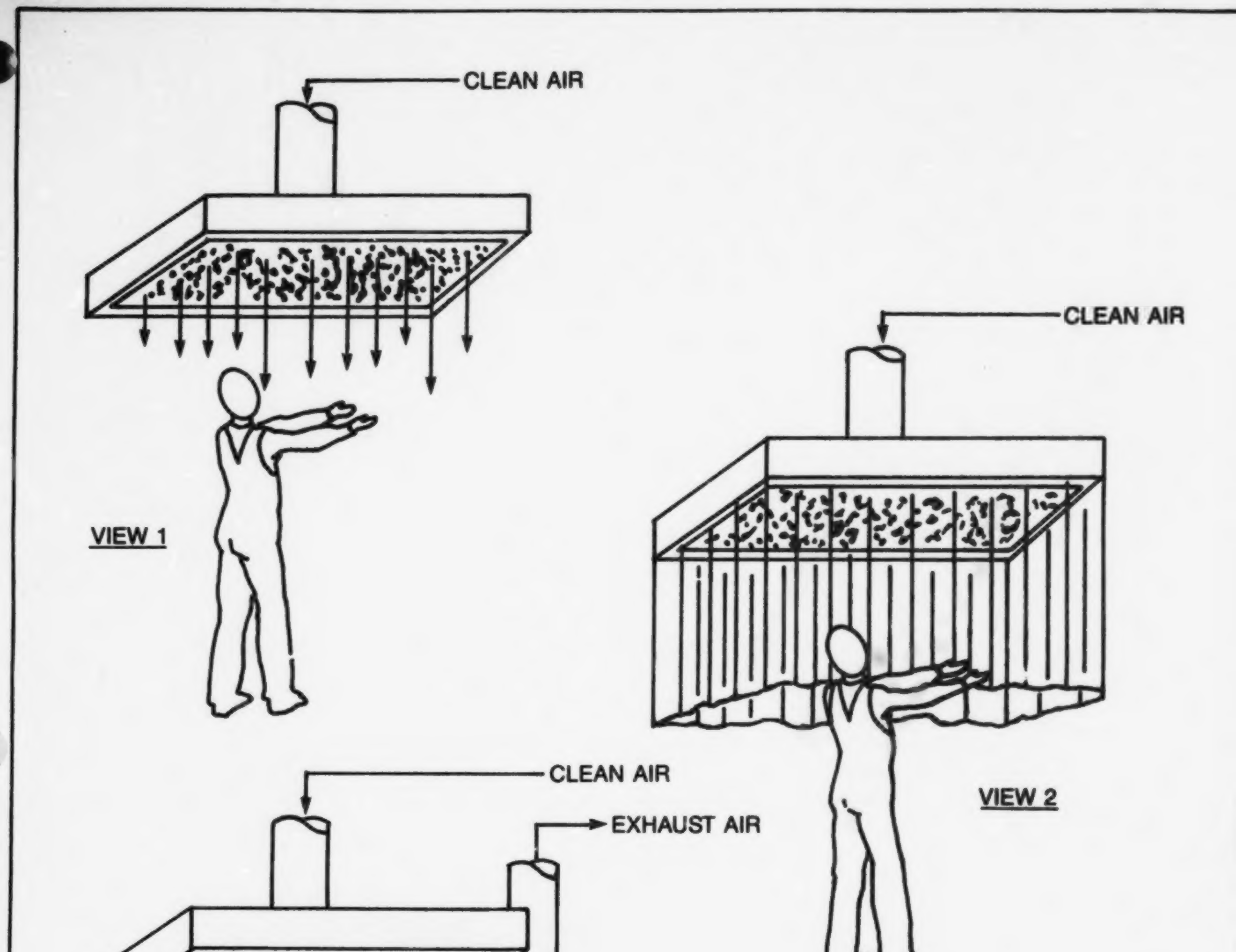
APPLICATION TIPS

LOCATE INLET IN LEAD FREE AREA

TEMPER INLET AIR – PROVIDE THERMOSTAT AT WORK STATION

PROVIDE OUTLET NOZZLE AS CLOSE TO BREATHING ZONE AS POSSIBLE

FIGURE 10


CLEAN AIR
VIEW 1
CLEAN AIR
VIEW 2
CLEAN AIR
EXHAUST AIR
VIEW 3

D. Decontamination of Clothing and Equipment

Lunchrooms, breakrooms and control rooms in lead battery plants can become contaminated with lead that is carried on employee work clothing and shoes. Contamination of a clean room facility interferes with its usefulness for reducing employee exposure and may, in fact, create an additional source of exposure. For this reason, it is important that some means be provided for employees to either remove, clean or cover their protective clothing and gear before entering a clean room facility. Figure 11 is an example of a clean room facility that can be used to minimize contaminating "clean" areas such as lunchrooms and break areas.

The OSHA standard for lead exposure (29 CFR 1910.1025) specifies that:

> "The employer shall assure that employees do not enter lunchroom facilities with protective work clothing or equipment unless surface lead has been removed by vacuuming, downdraft booth, or other cleaning method."

Surfaces of lunchroom tables, floors, and equipment should be kept clean of accumulations of lead dust. Weak solutions of acetic acid or vinegar can be used to wipe off surfaces prior to washing with water. Also, rolls of paper can be used to cover the table with a sheet of paper prior to use. After use, the used paper can be discarded and the table covered with a clean sheet.

The following methods could be used to remove lead dust from work clothing and shoes.

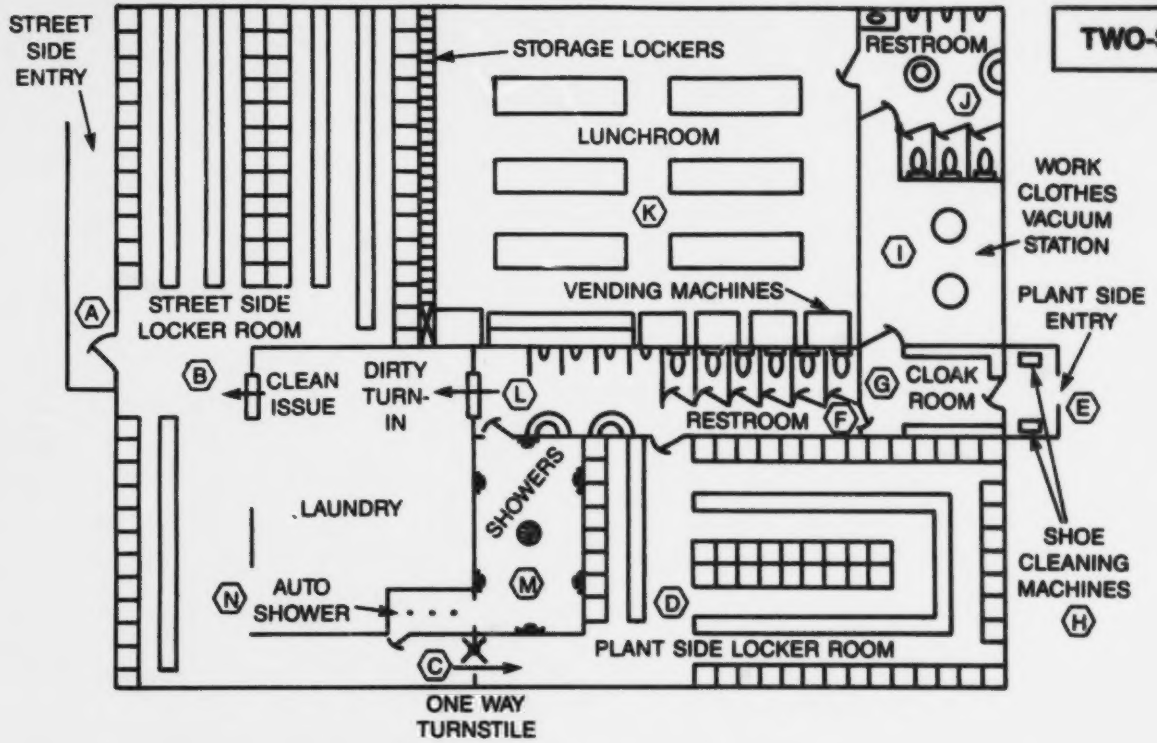
1. Clothes

a. Vacuuming

A vacuum cleaner is an acceptable method to remove particulate from clothing. The disadvantage of utilizing a vacuum cleaner is that it usually takes two people to do an adequate job. Care must be taken to purchase a vacuum cleaner that has a lot of suction and a high efficiency filter to prevent reexposure of employees by removing lead dust from clothing and resuspending it in the air. Vacuuming should be done before leaving the work station and/or before entering the washroom or lunchroom.

FIGURE 11

TWO-STAGE HYGIENE FACILITY


STREET SIDE ENTRY
Ⓐ
STREET SIDE LOCKER ROOM
Ⓑ
CLEAN ISSUE
DIRTY TURN-IN
Ⓛ
STORAGE LOCKERS
LUNCHROOM
Ⓚ
VENDING MACHINES
RESTROOM
Ⓙ
WORK CLOTHES VACUUM STATION
Ⓘ
PLANT SIDE ENTRY
Ⓔ
Ⓖ
CLOAK ROOM
RESTROOM
Ⓕ
LAUNDRY
SHOWERS
Ⓜ
Ⓝ
AUTO SHOWER
Ⓒ
ONE WAY TURNSTILE
Ⓓ
PLANT SIDE LOCKER ROOM
SHOE CLEANING MACHINES
Ⓗ

FACILITY FUNCTION/DESCRIPTION

1) THE FACILITY CAN BE ENTERED FROM THE STREET AT ONLY ONE POINT Ⓐ
2) STREET CLOTHES ARE REMOVED AND CLEAN WORKCLOTHES, HARDHAT, AND RESPIRATOR ARE ISSUED AND DONNED IN THE STREET-SIDE LOCKER ROOM Ⓑ
3) THE EMPLOYEE PASSES THROUGH A ONE-WAY TURNSTILE IN ORDER TO GET TO THE PLANT-SIDE LOCKER ROOM Ⓒ
4) THE EMPLOYEE DONS WORKBOOTS AND OTHER SAFETY GEAR IN THE PLANT-SIDE LOCKER ROOM, WHERE THEY ARE STORED Ⓓ
5) THERE IS ONLY ONE ENTRY TO THE PLANT Ⓔ
6) THE RESTROOM JUST INSIDE THE CLOAK ROOM IS READILY ACCESSIBLE DURING WORKING HOURS Ⓕ
7) THE CLOAK ROOM PROVIDES A PLACE TO STORE COATS, HARDHATS, GLOVES, AND RESPIRATORS DURING BREAK PERIODS Ⓖ
8) DURING LUNCH BREAK THE EMPLOYEE: FIRST CLEANS HIS BOOTS AT THE SHOE CLEANING MACHINES Ⓗ, LEAVES COAT & EQUIPMENT IN THE CLOAK ROOM Ⓖ. VACUUMS OFF HIS CLOTHES AT THE VACUUM STATION Ⓘ, PROCEEDS TO THE RESTROOM WHERE HE THOROUGHLY WASHES HIS HANDS Ⓙ. AND FINALLY ENTERS THE LUNCH ROOM Ⓚ
9) AT THE END OF THE SHIFT THE PROCEDURE IS AS FOLLOWS: THE EMPLOYEE CLEANS SHOES Ⓗ, REMOVES CONTAMINATED CLOTHING IN THE PLANT SIDE LOCKER ROOM Ⓓ, STORES BOOTS, ETC. IN PLANT-SIDE LOCKERS. TURNS IN DIRTY WORKCLOTHES, HARDHAT & RESPIRATOR TO LAUNDRY Ⓛ, PROCEEDS TO THE SHOWERS Ⓜ. HE THEN MUST PASS THROUGH AN AUTOMATIC SHOWER Ⓝ TO RETURN TO THE STREET-SIDE LOCKER ROOM Ⓑ. WHERE HE DRESSES AND LEAVES THE FACILITY Ⓐ

b. Clothes Change

Another method is to provide daily clothes changes prior to lunch.

c. Air Shower/Downdraft Booth

The use of air showers for exposure control in battery plants has been limited. Respiratory protection must be used inside these units. Figure 12 shows an example of an air shower for cleaning clothes.

2. Shoes

Shoe Cleaning Equipment

a. Mechanical brushing of shoes by brushes used to clean spikes on golf shoes are used by some battery plants to remove lead from the bottoms and sides of work shoes.

b. In addition to the mechanical washing/brushing of shoes, a hole can be drilled through the handle of a stiff tire washing brush through which a hose can be inserted. The employee steps up to a grate, turns on the hose and manually cleans the dirt from his/her boots. This is a very inexpensive and effective method. See Figure 13.

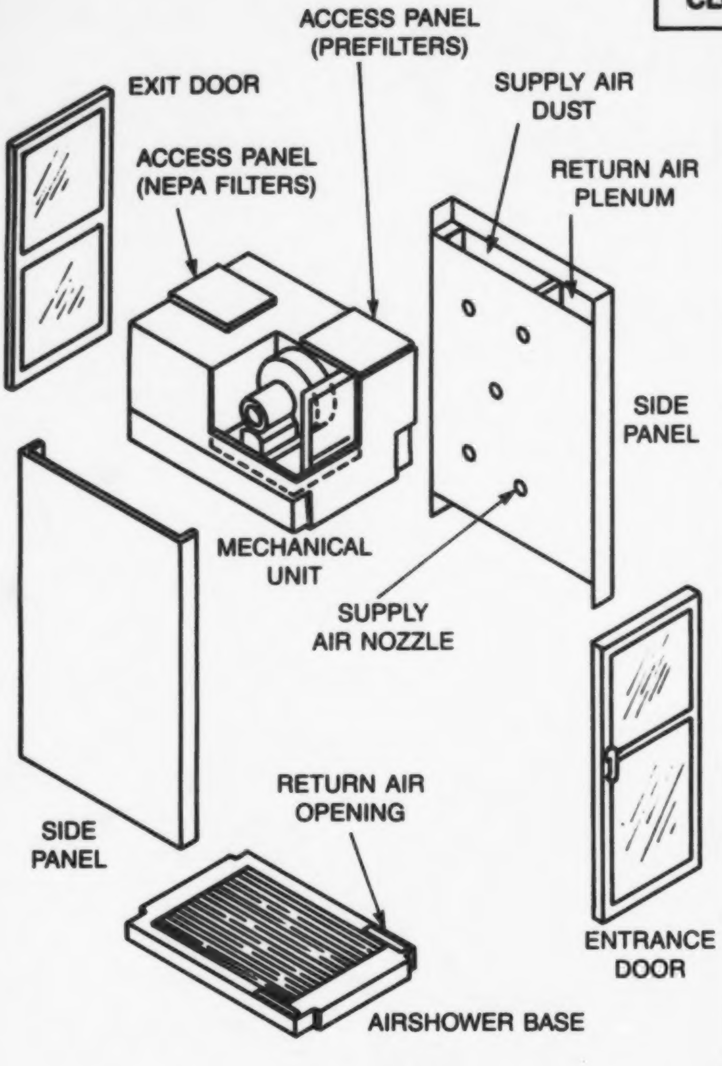
c. Vacuuming shoes. Most commercially available shoe cleaners use power brushes and a vacuum exhaust for cleaning. The majority of these vacuum/brush shoe cleaners are designed to clean one shoe at a time. The user steps up to the shoe cleaner, holds onto a handle for balance, starts the shoe cleaner, and inserts one shoe at a time for cleaning. Rotating brushes inside the machine loosen dust and dirt on the user's shoes and this dust is collected and removed via the vacuum exhaust. Variations on this basic shoe cleaner machine design include machines that clean both shoes at once and machines that use power brushes and water to scrub the shoes. Figure 14 is a drawing of a typical shoe cleaning machine.

d. Use of a tacking mat.

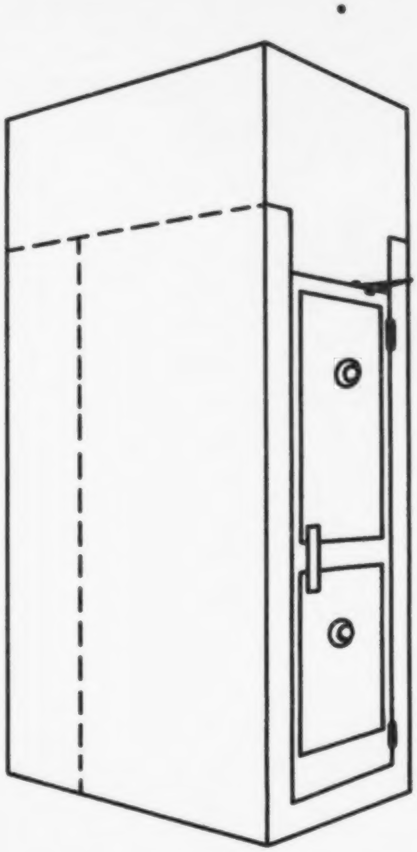
e. Removing shoes before entering cafeteria, putting on slippers, or provide shoe covering for use before entering lunchroom areas.

FIGURE 12

CLOTHES CLEANING AIR SHOWER


ACCESS PANEL (PREFILTERS)
EXIT DOOR
SUPPLY AIR DUST
ACCESS PANEL (NEPA FILTERS)
RETURN AIR PLENUM
SIDE PANEL
MECHANICAL UNIT
SUPPLY AIR NOZZLE
RETURN AIR OPENING
SIDE PANEL
ENTRANCE DOOR
AIRSHOWER BASE

EXPANDED VIEW



ASSEMBLED UNIT

APPLICATION TIPS

INSTALL AT ENTRANCES TO CLEAN-ROOMS, LUNCHROOMS, ETC.

ALLOW TIME FOR FULL USE BY EMPLOYEES.

PROVIDE DAILY CLEANING AND MAINTENANCE.

DESIGN CHARACTERISTICS

CHECK WITH SUPPLIER

FIGURE 13

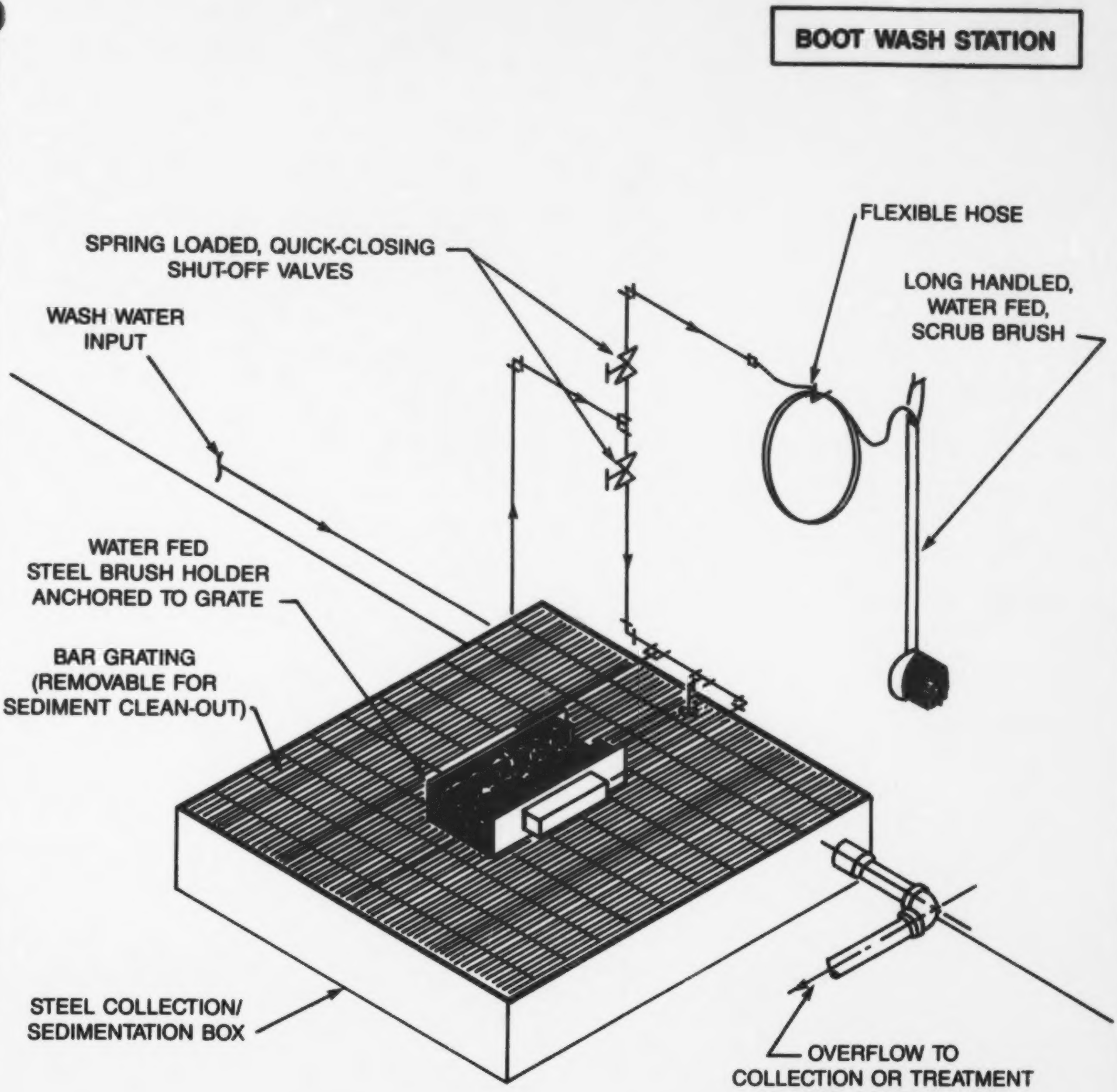
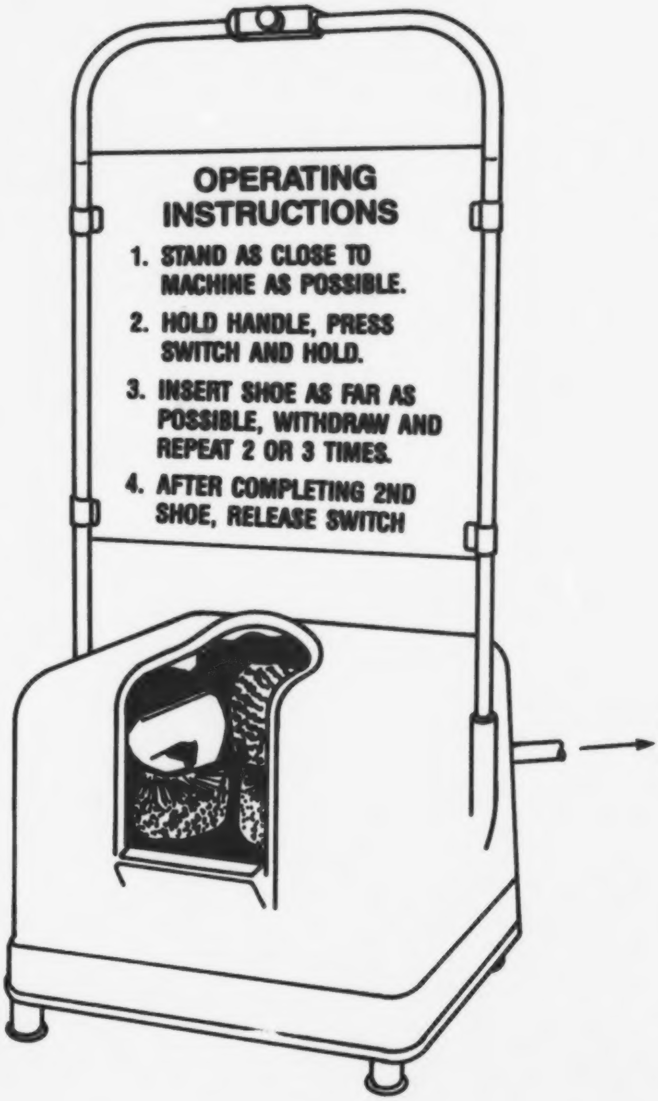

BOOT WASH STATION
SPRING LOADED, QUICK-CLOSING SHUT-OFF VALVES
FLEXIBLE HOSE
LONG HANDLED, WATER FED, SCRUB BRUSH
WASH WATER INPUT
WATER FED STEEL BRUSH HOLDER ANCHORED TO GRATE
BAR GRATING (REMOVABLE FOR SEDIMENT CLEAN-OUT)
STEEL COLLECTION/ SEDIMENTATION BOX
OVERFLOW TO COLLECTION OR TREATMENT OF LEAD CONTAMINATED WASTEWATER

FIGURE 14

SHOE CLEANING MACHINE



OPERATING INSTRUCTIONS

1. STAND AS CLOSE TO MACHINE AS POSSIBLE.
2. HOLD HANDLE, PRESS SWITCH AND HOLD.
3. INSERT SHOE AS FAR AS POSSIBLE, WITHDRAW AND REPEAT 2 OR 3 TIMES.
4. AFTER COMPLETING 2ND SHOE, RELEASE SWITCH

TO HEPA FILTRATION VACUUM SYSTEM OR PLANT CENTRAL VACUUM SYSTEM

E. Maintenance

Many of the control measures discussed in previous sections will help reduce the exposure of maintenance personnel. However, fixed engineering control measures are not always practicable for some maintenance operations, particularly those which arise from upset conditions.

1. Movement of contaminated equipment into shop areas has the potential for increasing exposures to shop personnel. For equipment parts that must be removed to the maintenance department for repair, a decontamination technique is to clean with acetic acid and check for lead contamination with sodium sulfide. Care should be taken that acetic acid does not enter waste water.

2. The exhaust ventilation systems for the welding operations should be maintained and up-graded, if necessary. Standard welding helmets are not intended to provide respiratory protection from lead fume and local exhaust and proper respiratory equipment must be used when welding lead contaminated materials.

3. Shops: All portable shop vacuum cleaners must be equipped with high efficiency filters capable of removing lead or must discharge into a secondary dust collection system. Vacuum the area to cleanup any oxide spills.

4. Control devices such as bag houses, wet collectors, vacuums, scrubbers, and other control equipment which control lead exposure must be inspected and tested on a regular schedule. For entry into control devices for repairs, provide a disposable full jump suit with hood, shoe coverings, and an air line respirator with an approved air supply or SCBA. Control devices and other equipment affecting lead exposure that need repair or cleaning must be repaired or cleaned promptly.

5. Maintenance people working in a specific department should wear at least the level of protective equipment required in that department. Hazards of individual jobs that maintenance people perform must be evaluated to determine proper personnel protective equipment.

6. Maintenance should be performed at a ventilated work table in the maintenance department if possible. Work tables with high efficiency HEPA filters are available for use in the plant.

7. When using torches on lead pumps or other equipment that has been exposed to lead provide local exhaust on the torch. Portable exhaust units are available.

8. Provide a wash-up sink for employees in the maintenance shop. Use waterless cleaners to keep lead out of water system.

9. The lead standard, 1910.1025(h)(1), prohibits the use of air hoses to blow off lead covered objects. Vacuum whenever possible.

10. A cleanup should be performed in the maintenance department at least each operating shift.

11. The company should study the feasibility and effectiveness of fully enclosing the shops and providing a positive pressure, filtered air system if the other items do not reduce exposures.

F. Cleanup

Maintenance and cleanup activities are similar. General plant cleanup should be performed at least once a year during plant shut down. Superstructures such as overhead beams and equipment should be carefully cleaned more frequently. Waste products generated during cleanup should be disposed of and treated in accordance with federal, state, or local regulations.

1. Section 1910.1025(h)(1) of the lead standard prohibits the use of air hoses to blow off lead covered objects. Vacuum whenever possible. Vacuum drops must be within reach of employees or they won't be used.

2. Do not dry sweep in lead areas. Vacuum, use a powered floor scrubber or sweeper or use a damp sweeping compound to clean floors around work areas.

3. Cover all lead scrap containers with a plastic bag before moving or storing. Do not reach into scrap barrels or bang them to remove scrap material. Do not overfill containers.

4. Catch drawers should be vacuumed or emptied in a properly ventilated area. Design clean out drawers that are not too big to handle or too heavy to empty. If dust is collected in a pail, it should be covered and disposed of properly.

5. If a high pressure water hose is used in cleaning the paste mixer and hopper, provide goggles, respirators, aprons, and other protective over clothing to protect employees from sprays and splashes. Written safety procedures must be installed for use of high pressure water hoses.

6. Floors should be sealed to aid in cleanup. The coating is most easily applied during or after pouring new floors.

7. Cover floors with damp or treated sweeping compound to help prevent settled dust from becoming airborne.

8. Use impervious materials such as plastic to facilitate cleanup of skids and racks.

G. High-Exposure Areas

To prevent general contamination of clean battery manufacturing areas, it is desirable to isolate processes generating significant emissions. A physical barrier will contain lead emissions and reduce their spread. Thus, as few people as possible are exposed and the number of emission sources contributing to exposure in any one place is reduced. This simplifies exposure evaluations, and makes the identification and control of major sources easier. For example, oxide mills and reclaim operations are often isolated from other plant operations.

VIII. SPECIFIC APPLICATIONS OF ENGINEERING CONTROL PRINCIPLES

The following illustrations are examples of some of the control measures discussed in earlier sections. All applications of engineering control are more successful if the following suggestions are followed:

Utilize engineering assistance competent and experienced in the design of industrial local exhaust and make-up air systems.

Consult with employees about controls.

Design hoods so that they are compatible with process equipment and work practices.

Train employees to use equipment effectively.

Enclose the process or operation as much as possible.

Use slots to evenly distribute the capture velocity of the air across the face of the hood.

Provide adequate exhaust. Too much exhaust ventilation may cause reentrainment of settled lead dust from adjacent racks and work areas.

Provide preventive maintenance, inspection, and cleaning.

Provide adequate make-up air and make sure clean air goes thru.

Prevent cross drafts.

Perform frequent ventilation checks at system. Appendix D contains information on ventilation measurements and maintenance.

If measured readings differ by 20% from recommended reading, the supervisor should be notified.

Daily ventilation checks of the pressure drop across the bag house should be performed.

TERMS AND ABBREVIATIONS USED ON DRAWINGS

he - hood entry loss in fractions of Velocity Pressure (VP)

VP - Velocity Pressure, inches of water

Ce - Coefficient of Entry, unitless

Q - Volume Flow rate in cubic feet per minute, cfm

V - Velocity in feet per minute, fpm

A - Area in square feet

scfm - Standard air (0.075 lbs. per cubic foot) flowing in cubic feet per minute

acfm - Actual air flow volume in cubic feet per minute

Vs - Velocity in slot

Vt - Minimum transport velocity in duct

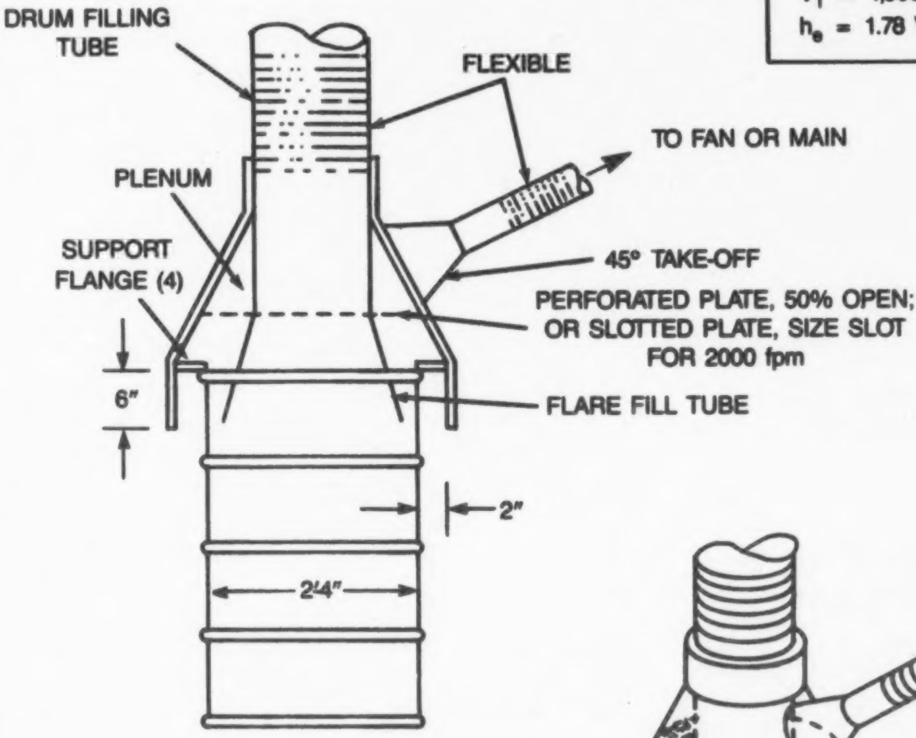
NOTE: ALL DRAWINGS AND RECOMMENDATIONS ASSUME STANDARD CONDITIONS (STP)

OXIDE DRUM FILLING

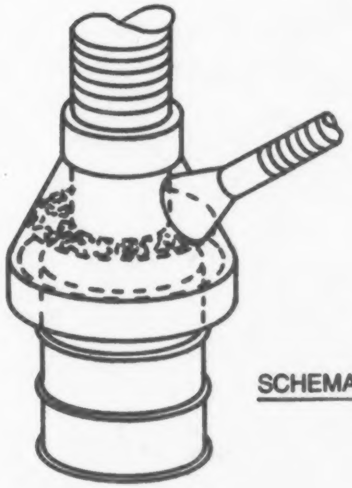
LOCAL EXHAUST VENTILATION

DESIGN CRITERIA

Q = 600 cfm
V_T = 4,500 fpm
$h_e = 1.78\ VP_{SLOT} + 0.25\ VP_{DUCT}$

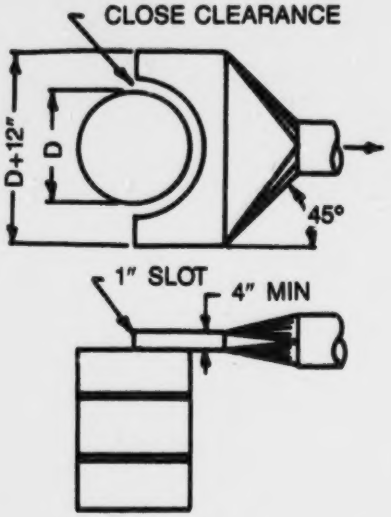

DRUM FILLING TUBE
FLEXIBLE
TO FAN OR MAIN
PLENUM
SUPPORT FLANGE (4)
45° TAKE-OFF
PERFORATED PLATE, 50% OPEN; OR SLOTTED PLATE, SIZE SLOT FOR 2000 fpm
6"
FLARE FILL TUBE
2"
2'4"

—SECTION—

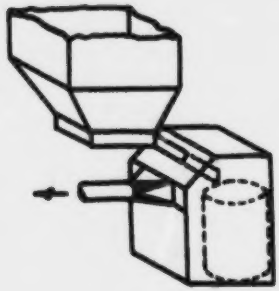


SCHEMATIC

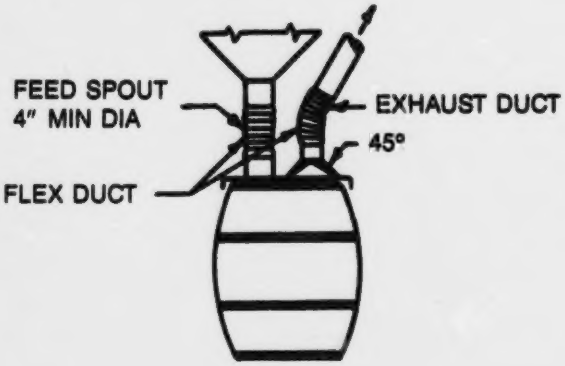
OXIDE BARREL FILLING
LOCAL EXHAUST VENTILATION


CLOSE CLEARANCE
D+12"
D
45°
1" SLOT
4" MIN

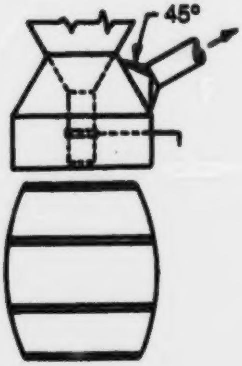
Q = 100 CFM/SQ FT BARREL TOP MIN
DUCT VELOCITY = 3500 MINIMUM
ENTRY LOSS = 0.25 VP + 1.78 SLOT VP
MANUAL LOADING.



Q = 150 CFM/SQ FT OPEN FACE AREA
DUCT VELOCITY = 3500 FPM MINIMUM
ENTRY LOSS = 0.25 VP FOR 45° TAPER


FEED SPOUT
4" MIN DIA
EXHAUST DUCT
45°
FLEX DUCT

Q = 50 CFM × DRUM DIA (FT) FOR WEIGHTED LID
150 CFM × DRUM DIA (FT) FOR LOOSE LID
DUCT VELOCITY = 3500 FPM MINIMUM
ENTRY LOSS = 0.25 VP

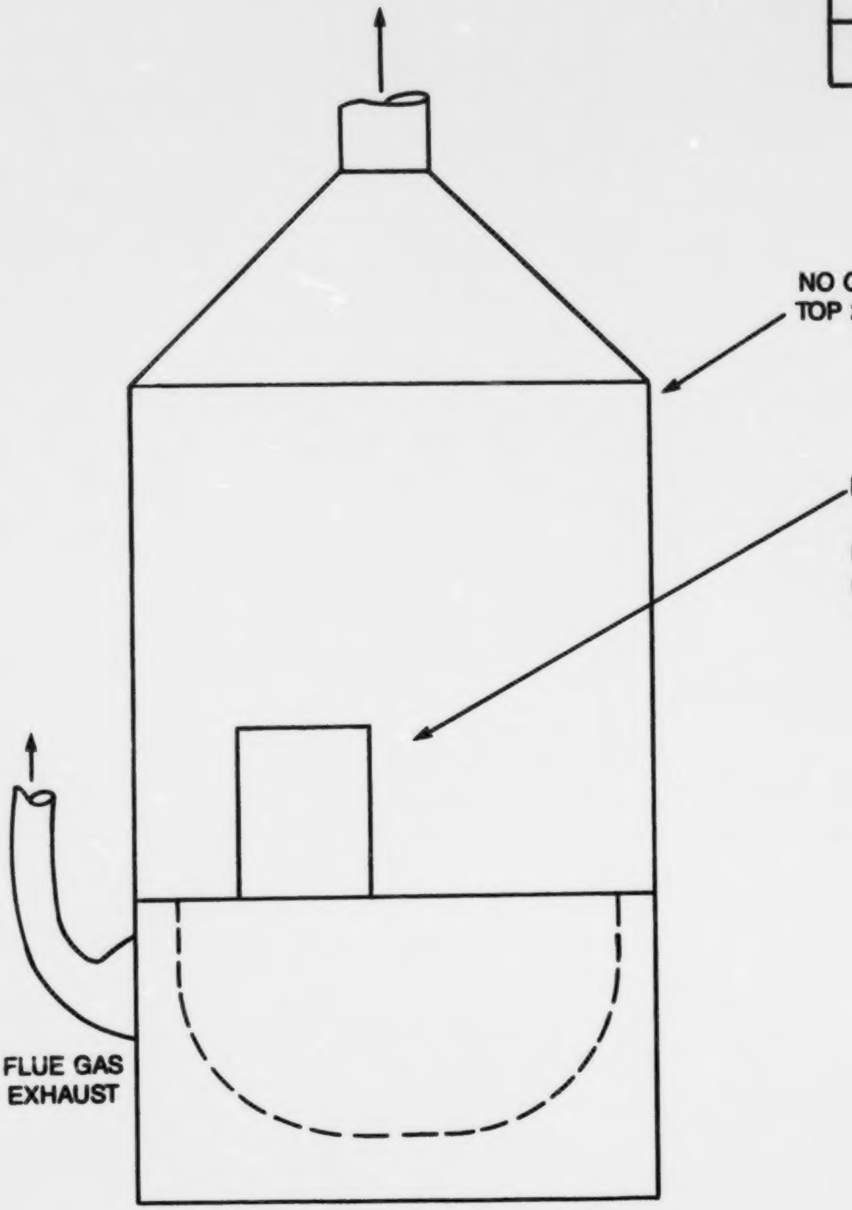


Q = 300-400 CFM
DUCT VELOCITY = 3500 FPM MIN
ENTRY LOSS = 0.25 VP

SOURCE: ACGIH VS-303

. GAS FIRED LEAD POT

CANOPY HOOD



NO OPENINGS IN TOP 2/3 OF HOOD

PROVIDE COVERS FOR OPEN AREAS;

MINIMIZE OPEN AREAS

USE FIRE PROOF MATERIAL TO CLOSE OPENING AROUND PIPES (OPTIONAL)

NOTE: DROSS POT HOOD IS NOT SHOWN

DESIGN CRITERIA

Q = 150 cfm/sq. ft. OPEN SPACE + 100 cfm/sq. ft. OF POT SURFACE

$V_T \geq$ 4,000 fpm

$V_{FACE} \geq$ 150 fpm

$h_e = 0.25\ VP_{DUCT}$ (WITH COVERS OFF)

LEAD POT AND DROSS HOOD

DESIGN CRITERIA

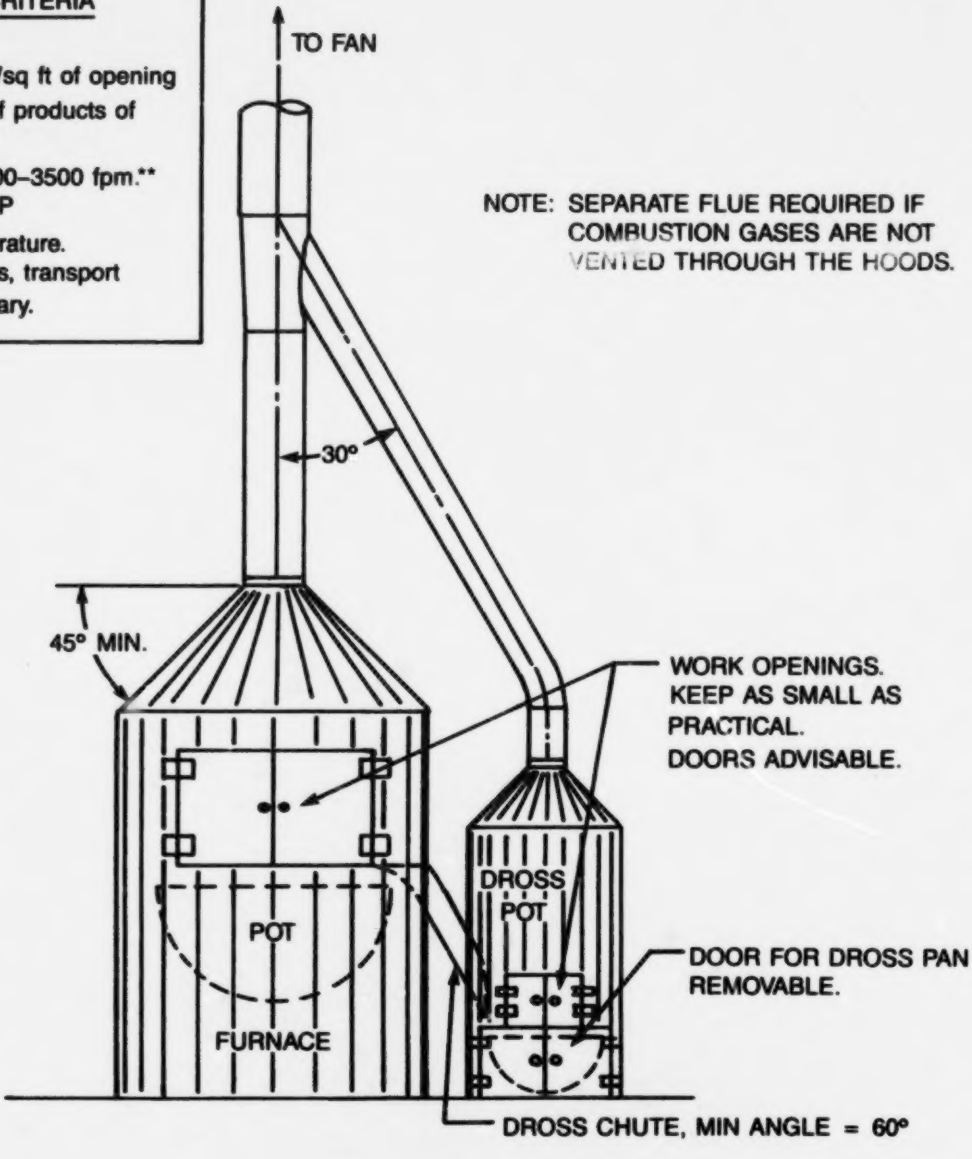
Q = 100–200 scfm/sq ft of opening plus volume of products of combustion.*

Duct velocity = 2000–3500 fpm.**

Entry loss = 0.50VP

*Correct for temperature.

**For horizontal runs, transport velocity is necessary.

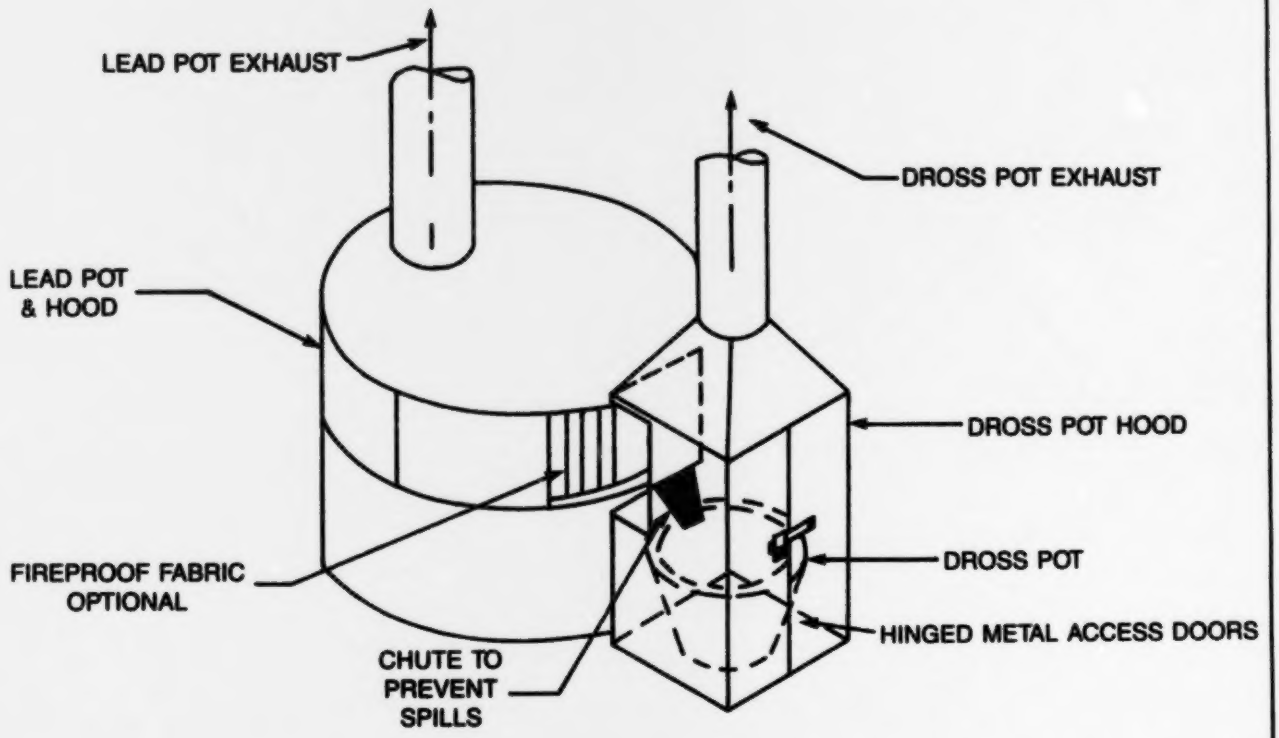

TO FAN
30°
45° MIN.
POT
FURNACE
DROSS POT
WORK OPENINGS. KEEP AS SMALL AS PRACTICAL. DOORS ADVISABLE.
DOOR FOR DROSS PAN REMOVABLE.
DROSS CHUTE, MIN ANGLE = 60°

NOTE: SEPARATE FLUE REQUIRED IF COMBUSTION GASES ARE NOT VENTED THROUGH THE HOODS.

SOURCE: ACGIH VS-906

LEAD POT

DROSS POT HOOD

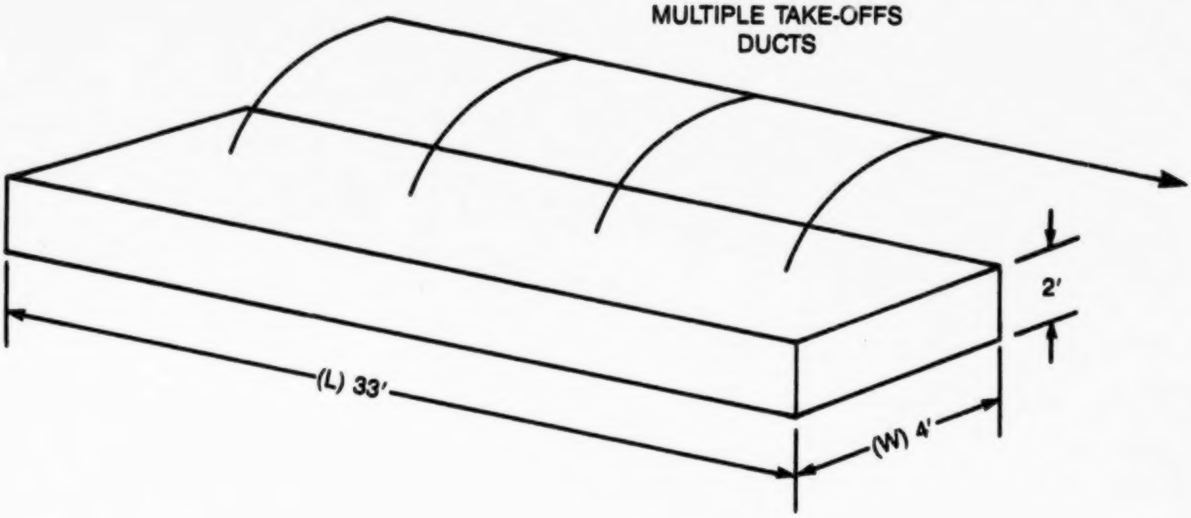

LEAD POT EXHAUST
DROSS POT EXHAUST
LEAD POT & HOOD
DROSS POT HOOD
FIREPROOF FABRIC OPTIONAL
DROSS POT
HINGED METAL ACCESS DOORS
CHUTE TO PREVENT SPILLS

DESIGN CRITERIA

ENCLOSURE TO PROVIDE CAPTURE VELOCITIES AT OPENINGS OF 350–500 FPM
TRANSPORT VELOCITIES IN DUCTS: ≥ 4,500 fpm
$h_e = 0.25\ VP_{DUCT}$

GRID CASTING

RECEIVING HOOD OVER LEAD LADLES


MULTIPLE TAKE-OFFS
DUCTS
2′
(L) 33′
(W) 4′

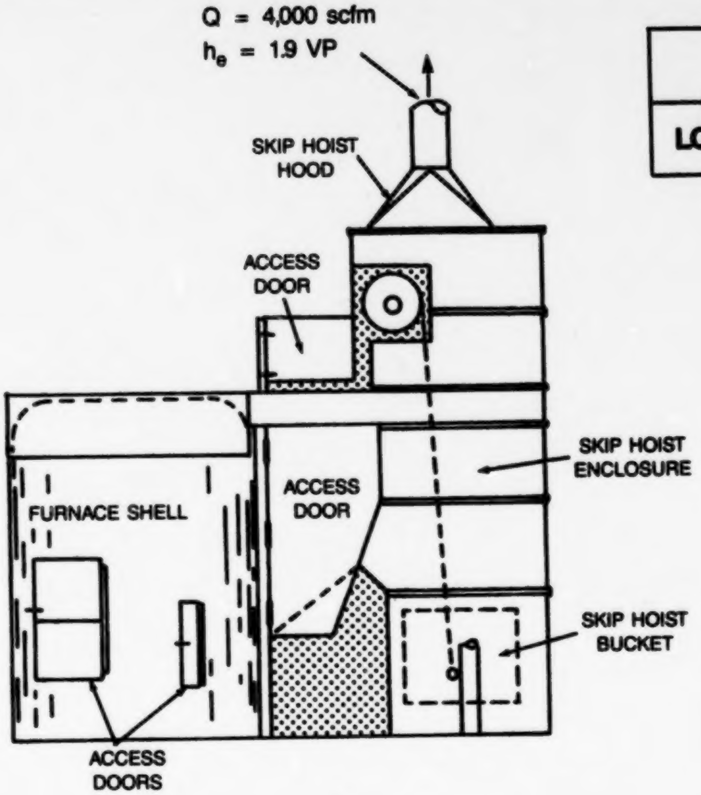
DESIGN CRITERIA

V_{FACE} = 50 fpm
Q = W • L • 50 (cfm)
$V_{DUCT} \geq 3500$ fpm
h_e = 0.50 VP (NO GATES)

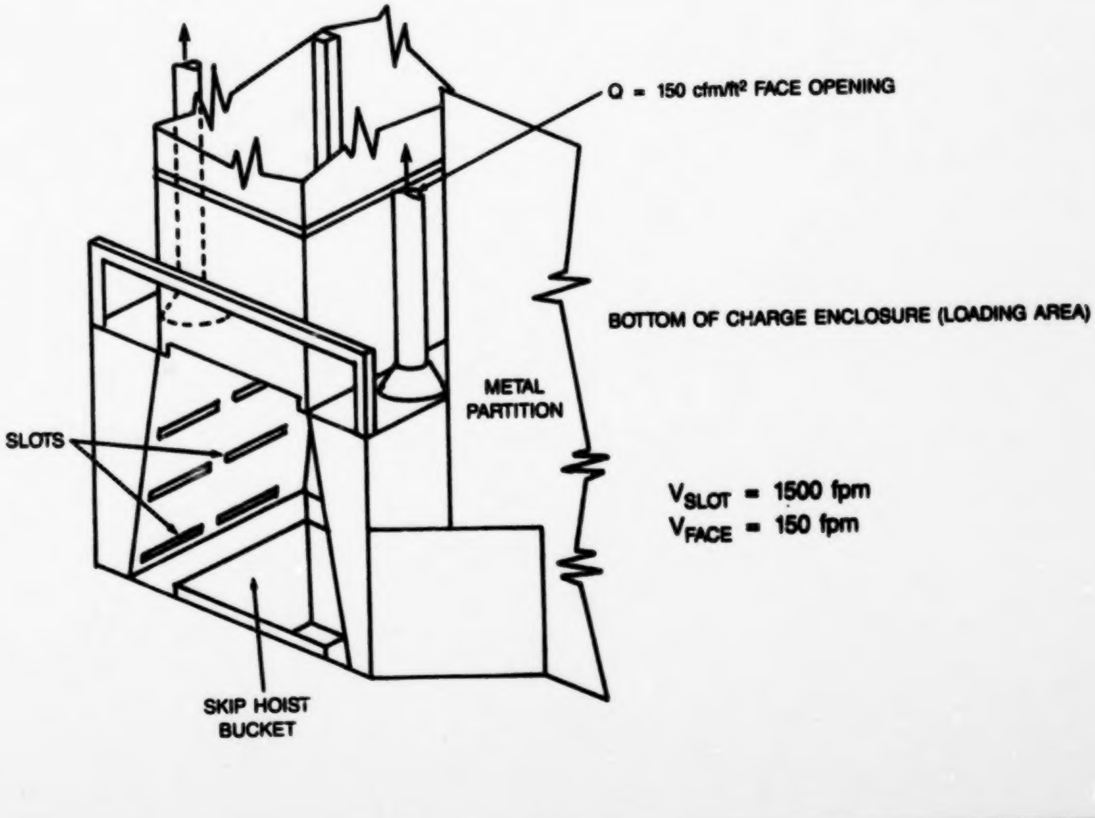
NOTE: HOOD IS DESIGNED TO REMOVE EXHAUST GASES AND FUGITIVE LEAD EMISSIONS CAUSED BY FLAMES IMPINGING ON LEAD CONTAMINATED EQUIPMENT.

DRUM OR SKIP HOIST

LOCAL EXHAUST VENTILATION



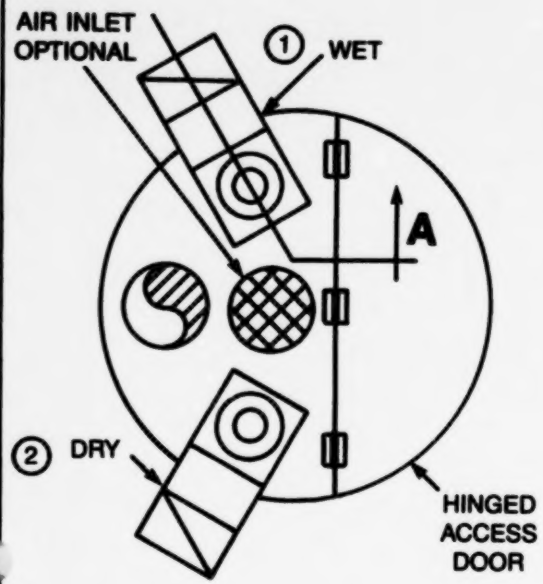
Q = 4,000 scfm
h_e = 1.9 VP
SKIP HOIST HOOD
ACCESS DOOR
SKIP HOIST ENCLOSURE
FURNACE SHELL
ACCESS DOOR
SKIP HOIST BUCKET
ACCESS DOORS



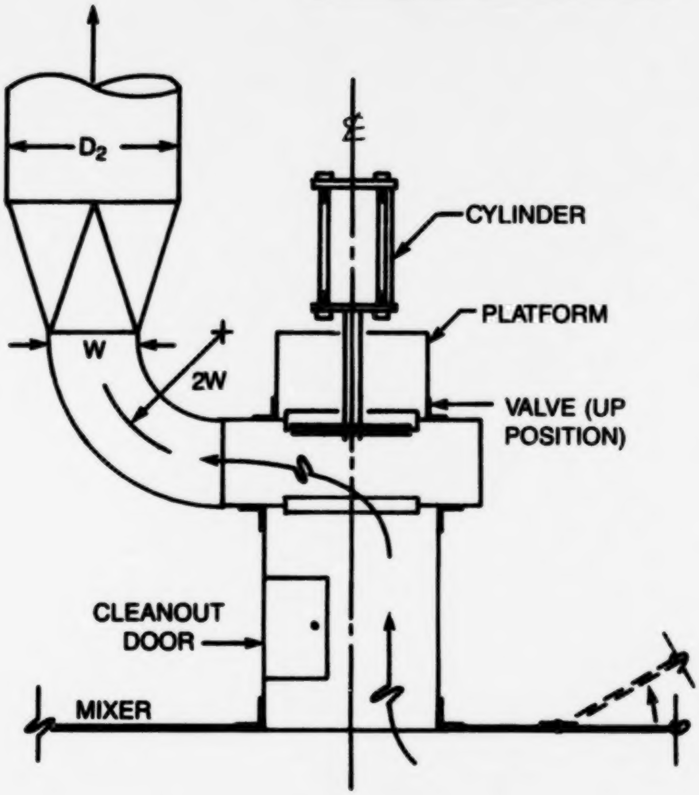
Q = 150 cfm/ft² FACE OPENING
BOTTOM OF CHARGE ENCLOSURE (LOADING AREA)
METAL PARTITION
SLOTS
V_{SLOT} = 1500 fpm
V_{FACE} = 150 fpm
SKIP HOIST BUCKET

PASTE MIXER

DUAL MIXER EMISSION CONTROLS


AIR INLET OPTIONAL
①
WET
A
②
DRY
HINGED ACCESS DOOR

MIXER PLAN VIEW

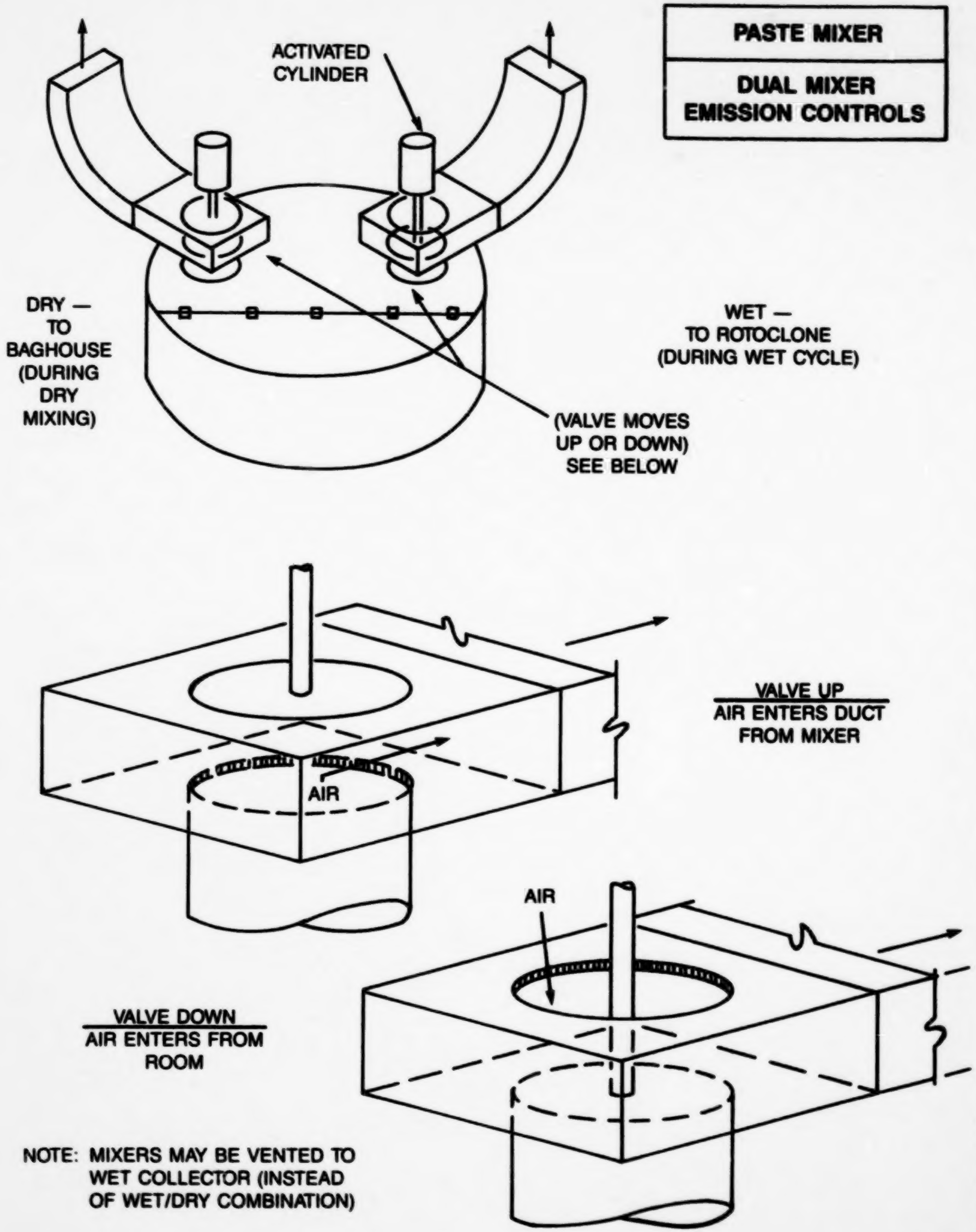

D_2
℄
CYLINDER
PLATFORM
W
2W
VALVE (UP POSITION)
CLEANOUT DOOR
MIXER

SECTION VIEW A

DESIGN CRITERIA

$Q_{MAX.}$ = 400 CFM/SQ. FT. × AREA OF OPEN ACCESS DOOR, SQ. FT.
$V_{TRANSPORT}$ = 4,500 fpm (WHEN ACCESS DOOR OPEN, VALVE IN UP POSITION)
$h_e = 1.6\ VP_{DUCT}$ (ACCESS DOOR OPEN, VALVE IN UP POSITION)

NOTE: INSTEAD OF OPENING DOOR FOR AIR INLET ON WET CYCLE, AN OPTIONAL AIR INLET CAN BE INSTALLED.
MANUFACTURERS OF MIXERS SET AIR VOLUME REQUIREMENTS ON MIXER.



PASTE MIXER

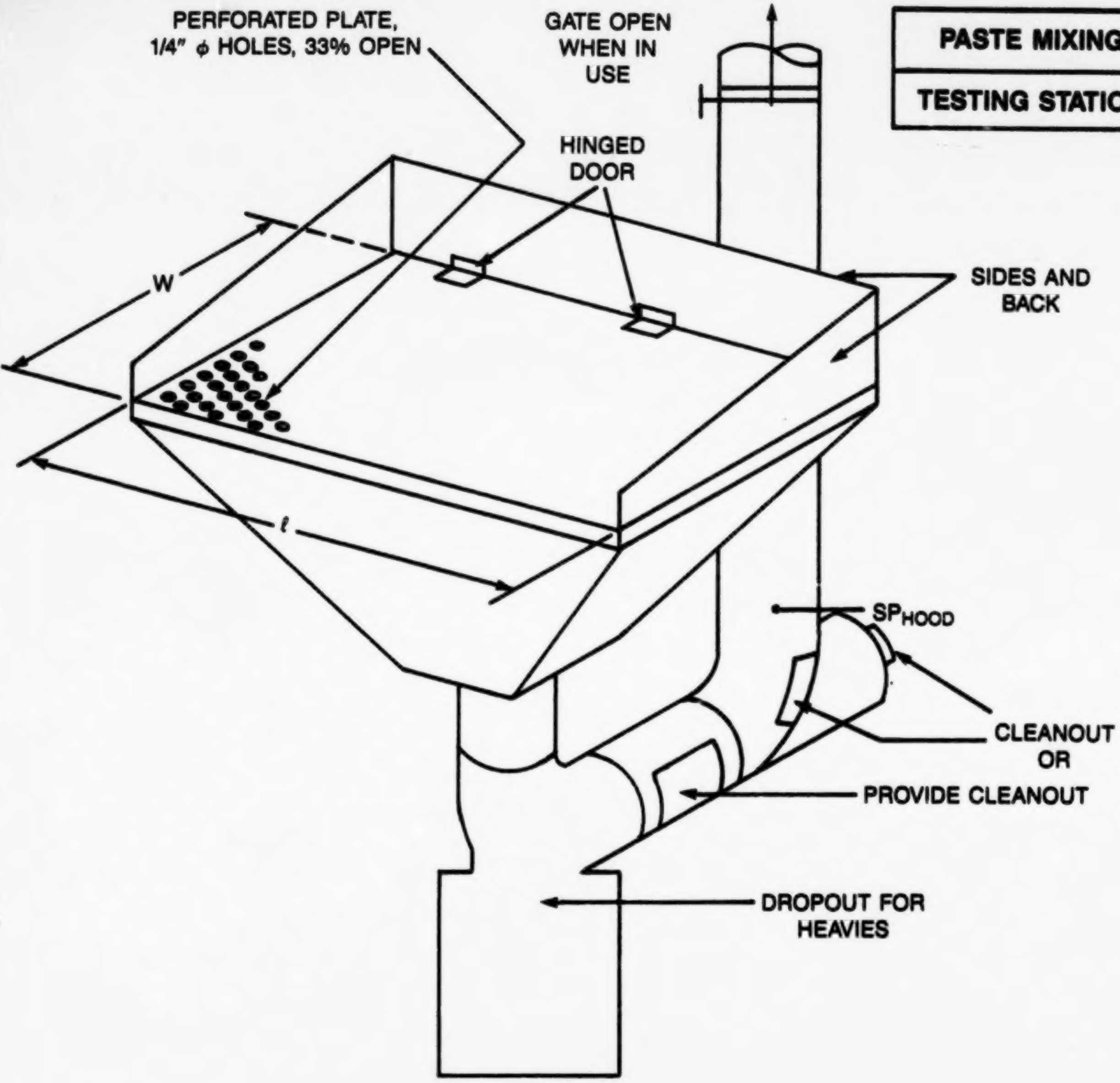
DUAL MIXER EMISSION CONTROLS

ACTIVATED CYLINDER
DRY — TO BAGHOUSE (DURING DRY MIXING)
WET — TO ROTOCLONE (DURING WET CYCLE)
(VALVE MOVES UP OR DOWN) SEE BELOW
AIR
VALVE UP
AIR ENTERS DUCT FROM MIXER
AIR
VALVE DOWN
AIR ENTERS FROM ROOM

NOTE: MIXERS MAY BE VENTED TO WET COLLECTOR (INSTEAD OF WET/DRY COMBINATION)

PASTE MIXING

TESTING STATION


PERFORATED PLATE, 1/4" ϕ HOLES, 33% OPEN
GATE OPEN WHEN IN USE
HINGED DOOR
W
SIDES AND BACK
ℓ
SP_{HOOD}
CLEANOUT OR
PROVIDE CLEANOUT
DROPOUT FOR HEAVIES

FOR INFREQUENTLY USED STATION

- SUBSTANTIAL CONSTRUCTION
- BUILD TO NECESSARY SURFACE DIMENSIONS, W AND ℓ

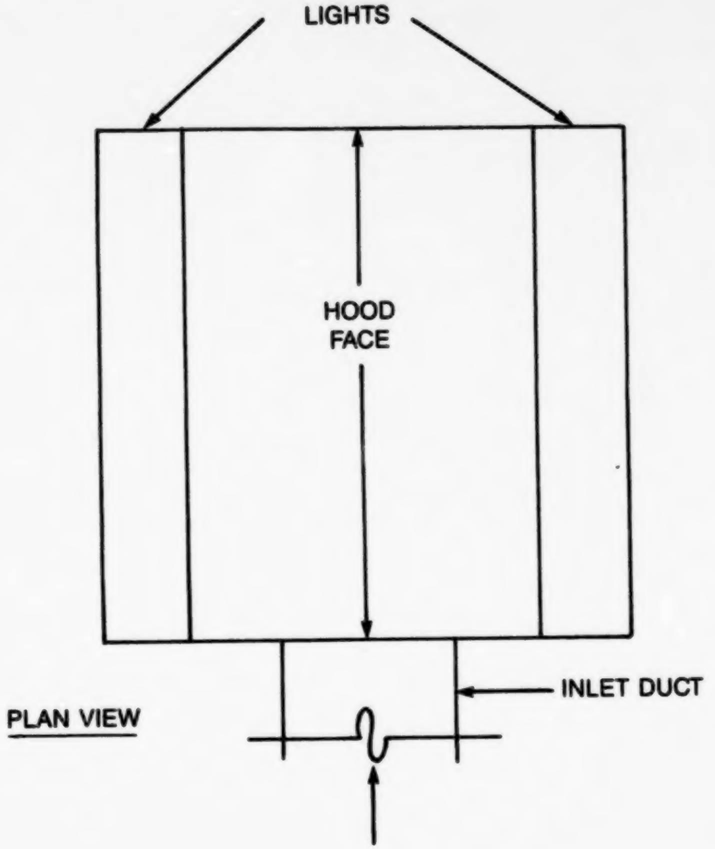
DESIGN CRITERIA

$Q = 300 \cdot W \cdot \ell$

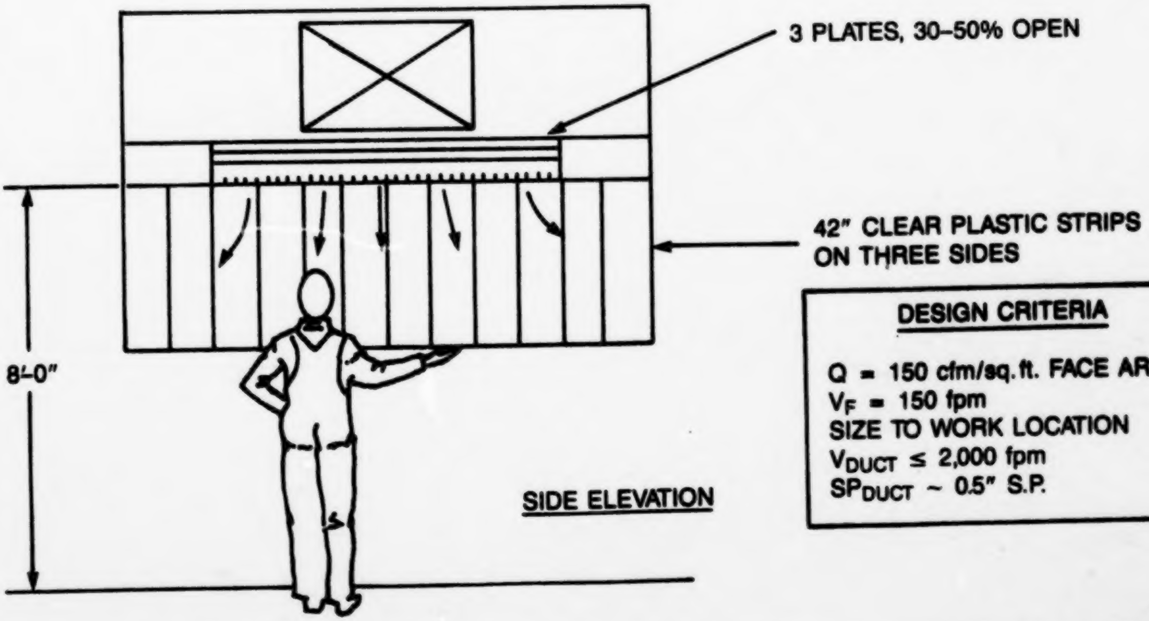
$V_{TRANSPORT} \geq 4{,}500$ fpm

$h_e = 2.8\ VP_{DUCT}$ (Gate fully open, or no gate)

SUPPLIED AIR ISLAND


LIGHTS
HOOD
FACE
INLET DUCT

PLAN VIEW


3 PLATES, 30–50% OPEN
42" CLEAR PLASTIC STRIPS
ON THREE SIDES
8'-0"

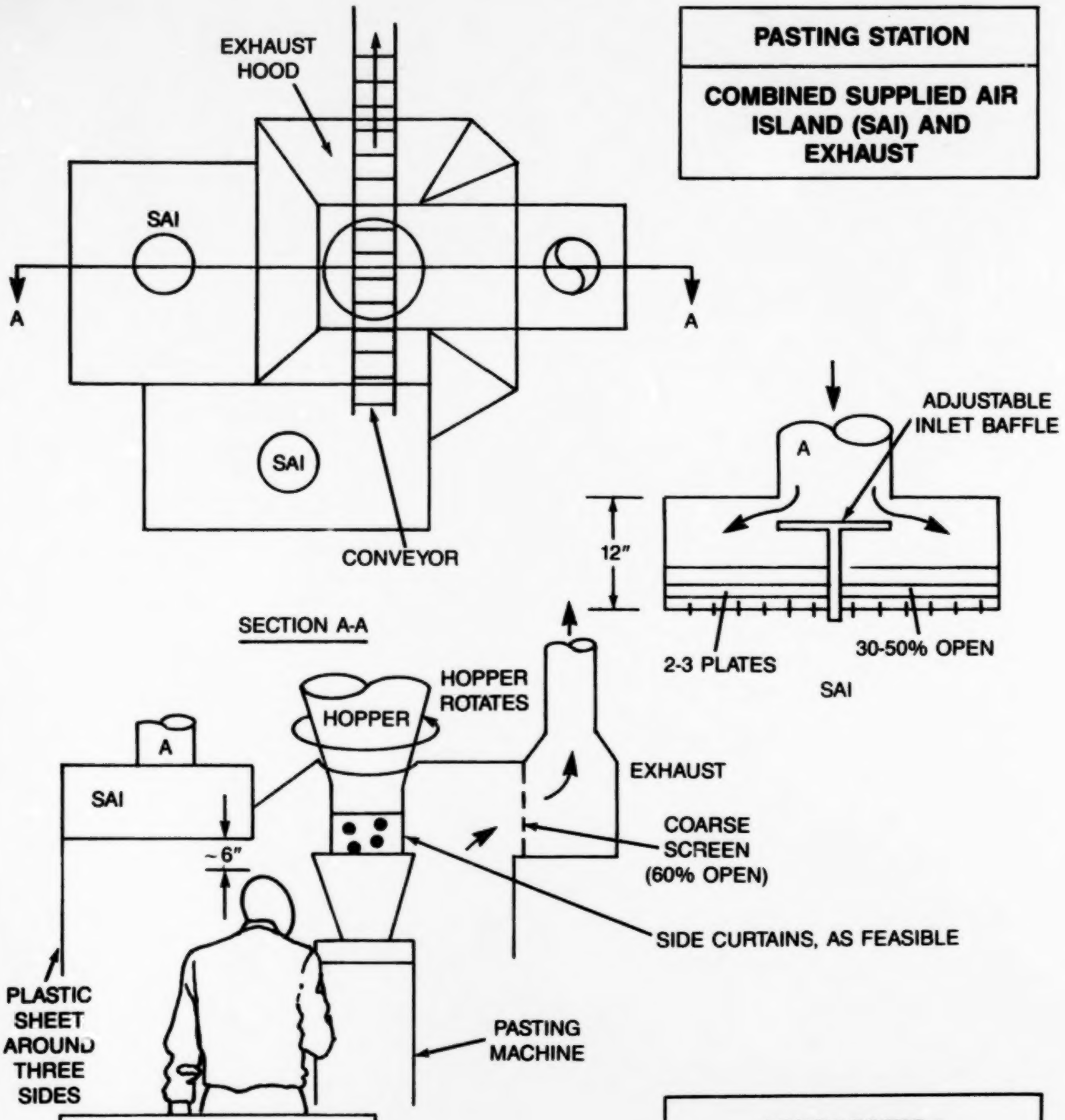
SIDE ELEVATION

DESIGN CRITERIA

Q = 150 cfm/sq.ft. FACE AREA
V_F = 150 fpm
SIZE TO WORK LOCATION
$V_{DUCT} \leq$ 2,000 fpm
$SP_{DUCT} \sim$ 0.5" S.P.

PASTING STATION

COMBINED SUPPLIED AIR ISLAND (SAI) AND EXHAUST


EXHAUST HOOD
SAI
A
A
SAI
CONVEYOR
ADJUSTABLE INLET BAFFLE
A
12"
2-3 PLATES
30-50% OPEN
SAI
SECTION A-A
HOPPER
HOPPER ROTATES
A
SAI
~6"
EXHAUST
COARSE SCREEN (60% OPEN)
SIDE CURTAINS, AS FEASIBLE
PLASTIC SHEET AROUND THREE SIDES
PASTING MACHINE

DESIGN CRITERIA

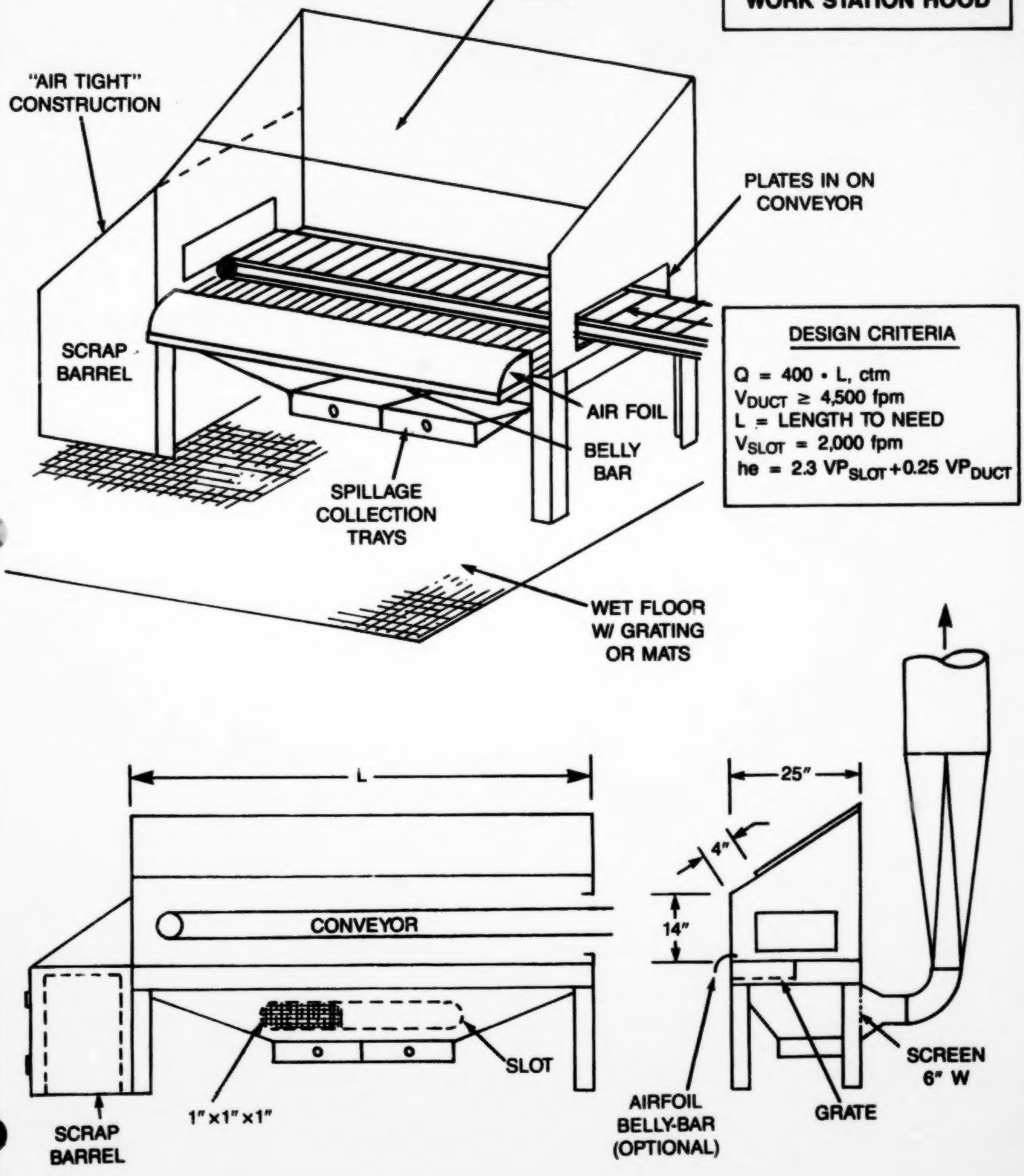
SAI
SIZE FOR WORK PLACE
V_F = 150 fpm
SP ~ 0.2-0.3" W.G. AT "A"
$Q \geq Q_{EXHAUSTED}$

DESIGN CRITERIA

EXHAUST
SIZE FOR PROCESS
V_D = 4,500 fpm
Q = 300 cfm/SQ FT HOOD FACE
he = 1.0 VP_{DUCT}

PASTING TAKE-OFF

WORK STATION HOOD


"GLASS"
"AIR TIGHT" CONSTRUCTION
PLATES IN ON CONVEYOR
SCRAP BARREL
AIR FOIL
BELLY BAR
SPILLAGE COLLECTION TRAYS
WET FLOOR W/ GRATING OR MATS
L
CONVEYOR
SLOT
1" × 1" × 1"
SCRAP BARREL
25"
4"
14"
AIRFOIL BELLY-BAR (OPTIONAL)
GRATE
SCREEN 6" W

DESIGN CRITERIA

$Q = 400 \cdot L$, cfm

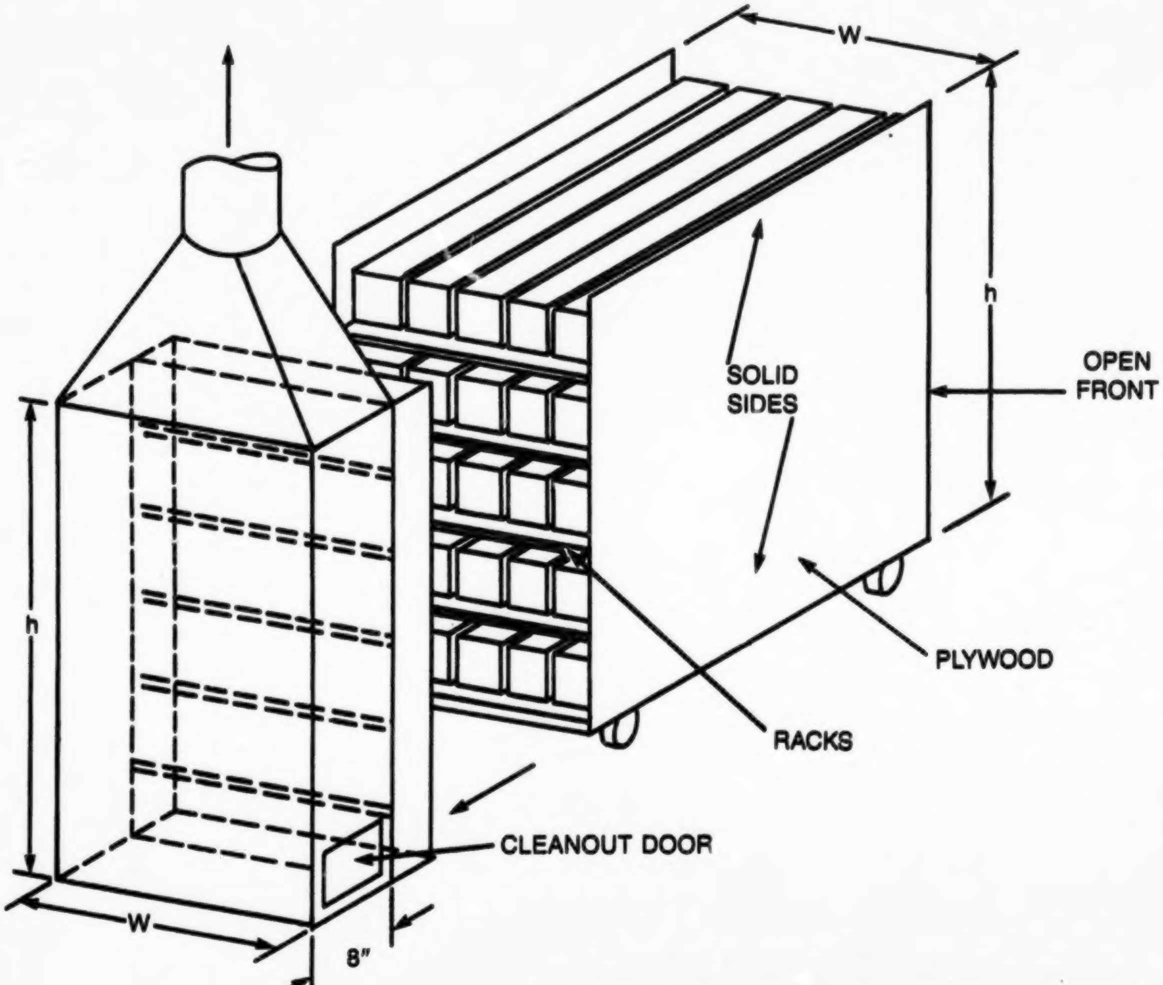
$V_{DUCT} \geq 4{,}500$ fpm

L = LENGTH TO NEED

$V_{SLOT} = 2{,}000$ fpm

$h_e = 2.3\ VP_{SLOT} + 0.25\ VP_{DUCT}$

PLATE STORAGE RACK HOOD

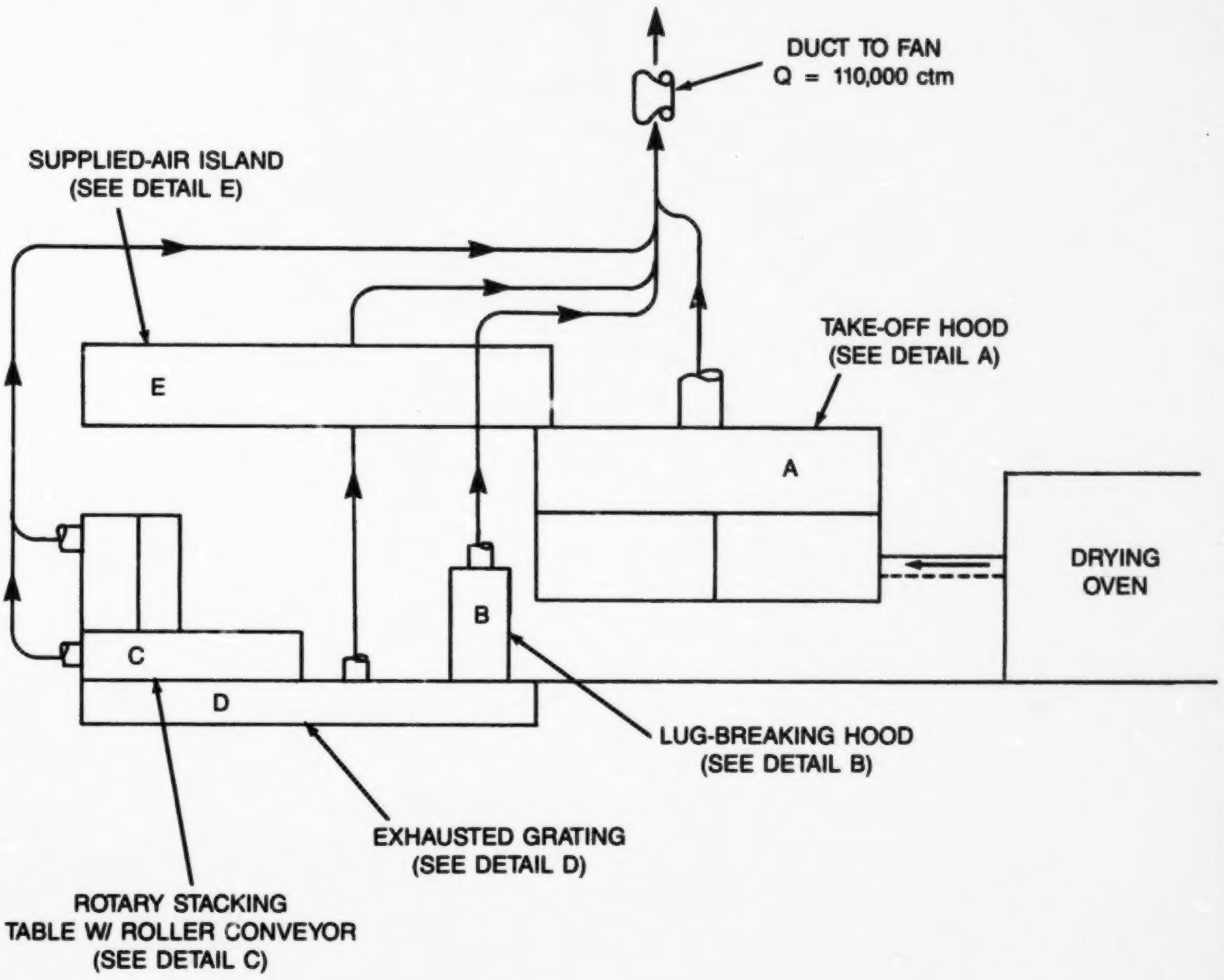

W
h
OPEN FRONT
SOLID SIDES
PLYWOOD
RACKS
CLEANOUT DOOR
h
W
8"

DESIGN CRITERIA

BUILD RACK TO BUTT UP AGAINST HOOD
$Q = 250 \cdot W \cdot h$
$V_{SLOT} = 2{,}000$ fpm
$h_e = 1.4\ VP_{DUCT}$
$V_{DUCT} \geq 4{,}500$ fpm

INTEGRATED CONTROLS

PLATE TAKE-OFF OPERATION


DUCT TO FAN
Q = 110,000 cfm
SUPPLIED-AIR ISLAND
(SEE DETAIL E)
TAKE-OFF HOOD
(SEE DETAIL A)
E
A
DRYING
OVEN
B
C
D
LUG-BREAKING HOOD
(SEE DETAIL B)
EXHAUSTED GRATING
(SEE DETAIL D)
ROTARY STACKING
TABLE W/ ROLLER CONVEYOR
(SEE DETAIL C)

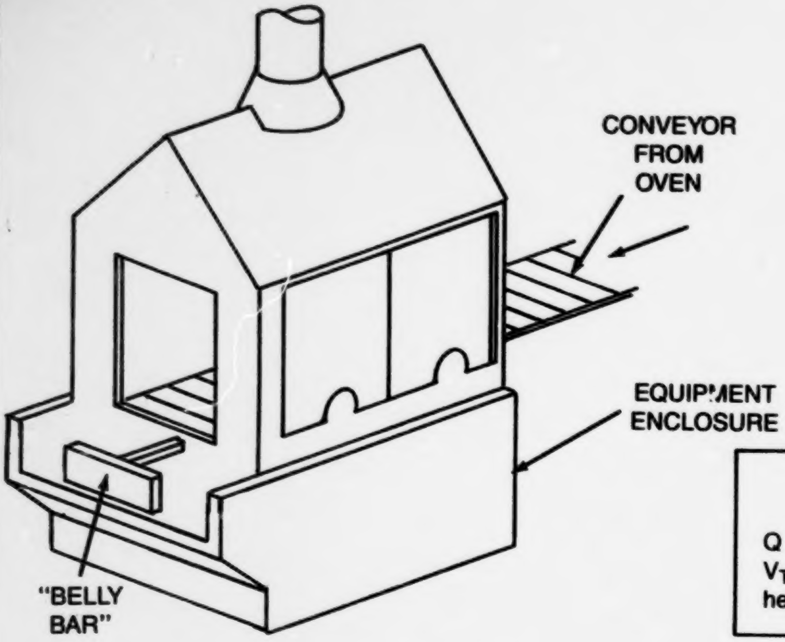
SOURCE: GBC, READING, PA

INTEGRATED CONTROLS

PLATE TAKE-OFF

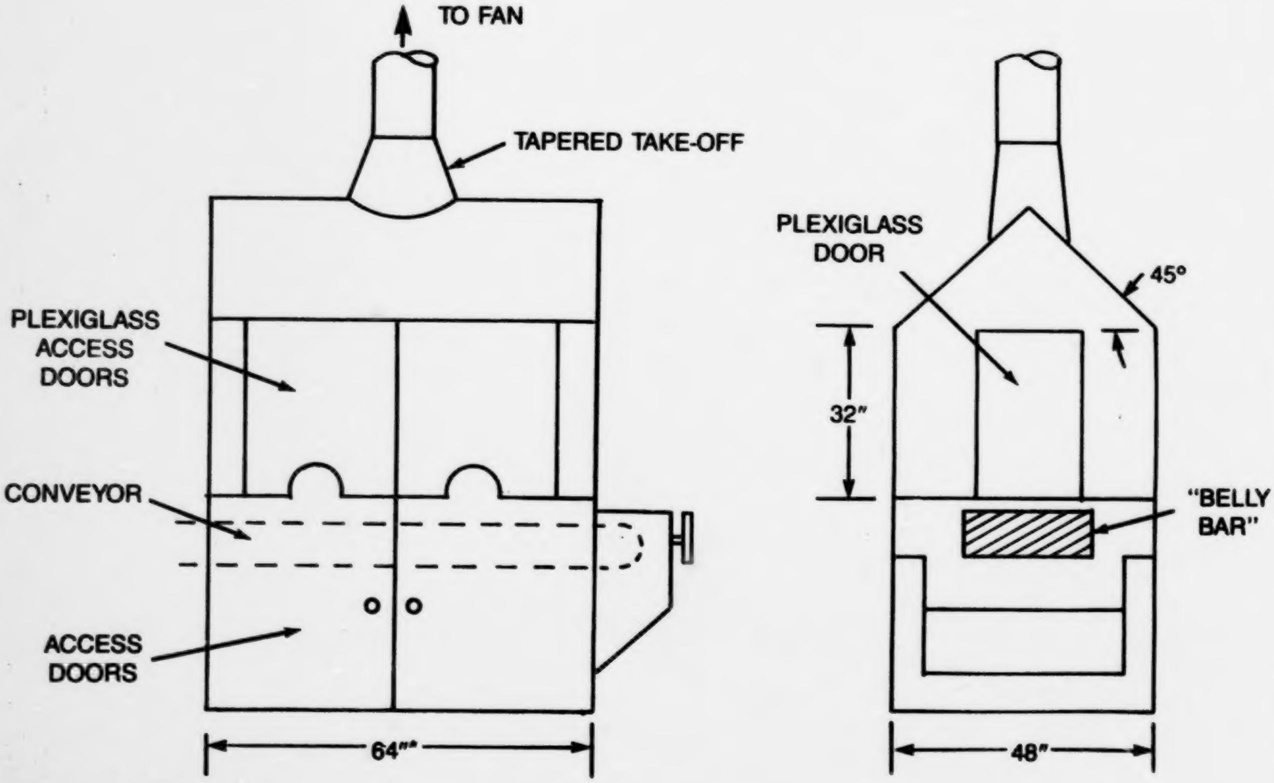
DETAIL A

**TAKE-OFF HOOD
(AT EXIT OF OVEN)**


CONVEYOR
FROM
OVEN
EQUIPMENT
ENCLOSURE
"BELLY
BAR"

DESIGN CRITERIA

Q = 250 ctm/SQ FT OPEN + 1000 ctm
V_T = 4500 ctm
he = 0.25 VP


TO FAN
TAPERED TAKE-OFF
PLEXIGLASS
ACCESS
DOORS
CONVEYOR
ACCESS
DOORS
64"*
PLEXIGLASS
DOOR
45°
32"
"BELLY
BAR"
48"

*GBC MEASUREMENTS
SIZE HOODS TO MEET EQUIPMENT NEEDS

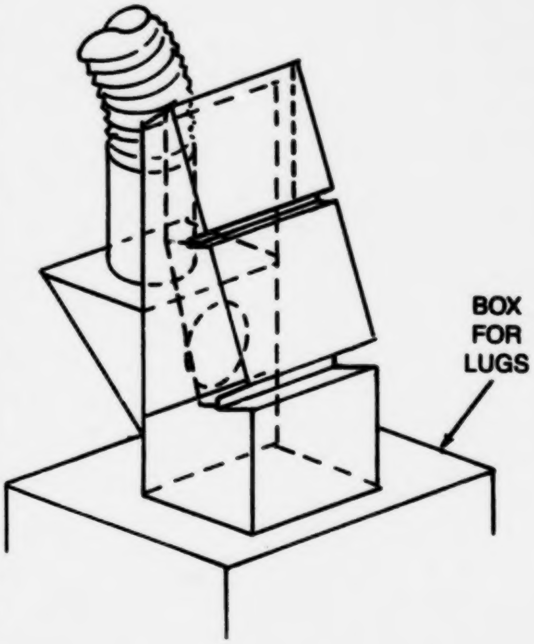
SOURCE: GBC, READING, PA

INTEGRATED CONTROLS

PLATE TAKE-OFF

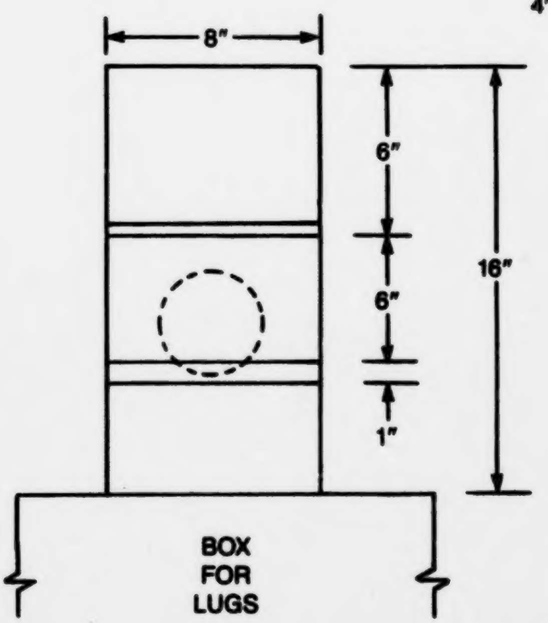
DETAIL B

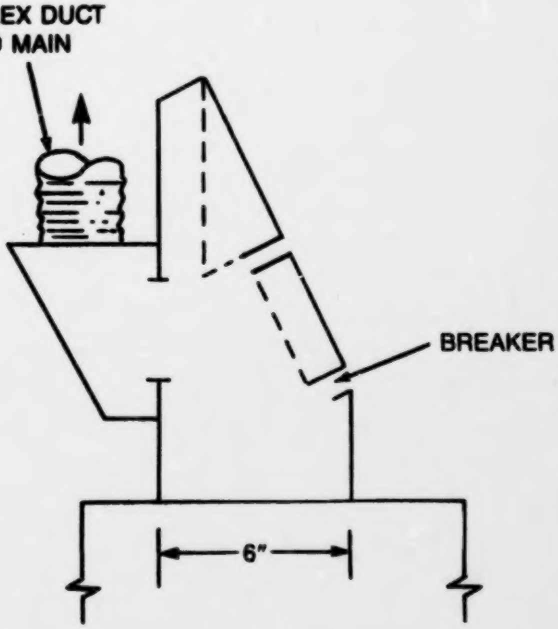
LUG BREAKING STATION


BOX
FOR
LUGS

DESIGN CRITERIA

Q = 400 cfm/SQ FT OPEN AREA
$V_T \geq 4{,}500$ fpm
SIZE TO FIT OPERATION
he = 3 VP_{DUCT}


8"
6"
6"
1"
16"
BOX
FOR
LUGS


4" FLEX DUCT
TO MAIN
BREAKER
6"

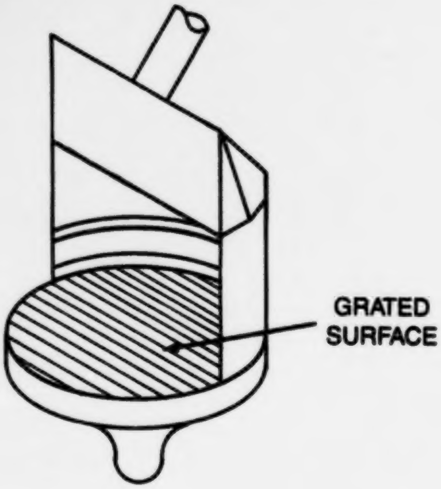
INTEGRATED CONTROLS

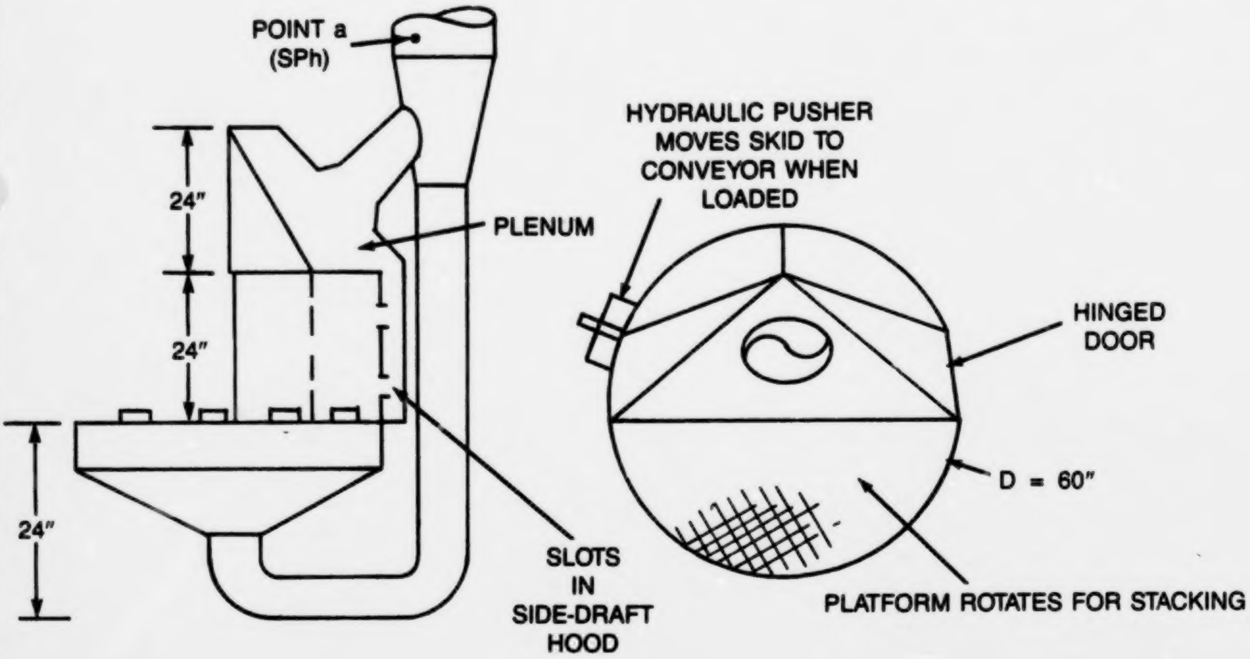
PLATE TAKE-OFF

DETAIL C

STACKING TABLE
ROTARY, W/ CONVEYOR

SIZE TO FIT OPERATION


GRATED
SURFACE


POINT a
(SPh)
24"
24"
24"
PLENUM
SLOTS
IN
SIDE-DRAFT
HOOD
HYDRAULIC PUSHER
MOVES SKID TO
CONVEYOR WHEN
LOADED
HINGED
DOOR
D = 60"
PLATFORM ROTATES FOR STACKING

DESIGN CRITERIA

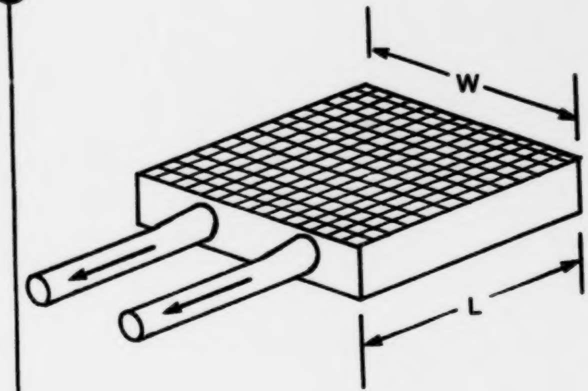
Q = 150 cfm/SQ FT DOWNDRAFT AREA + 150 cfm/SQ FT SIDE HOOD AREA
V_{SLOT} = 2000 fpm
he = NA (USE BLAST GATES TO BALANCE SYSTEM; PROVIDE AT LEAST −5" STATIC PRESSURE AT POINT a)
$V_T \geq$ 4,500 fpm

INTEGRATED CONTROLS

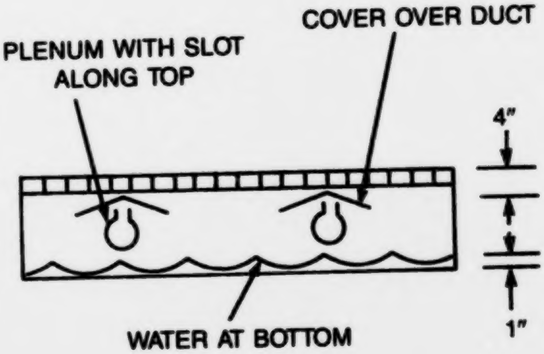
PLATE TAKE-OFF

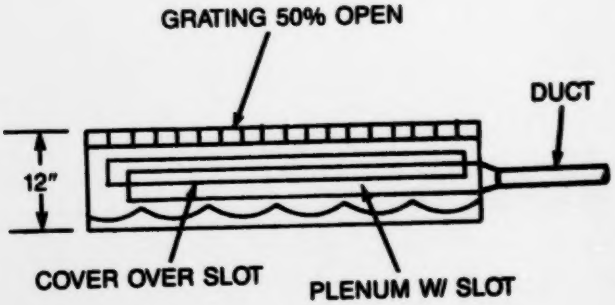
DETAIL D

GRATED/EXHAUSTED FLOOR



- SIZE TO NEED
- POSITION DUCT WELL ABOVE WATER (H_2O IN BAGHOUSE IS A POTENTIAL PROBLEM)

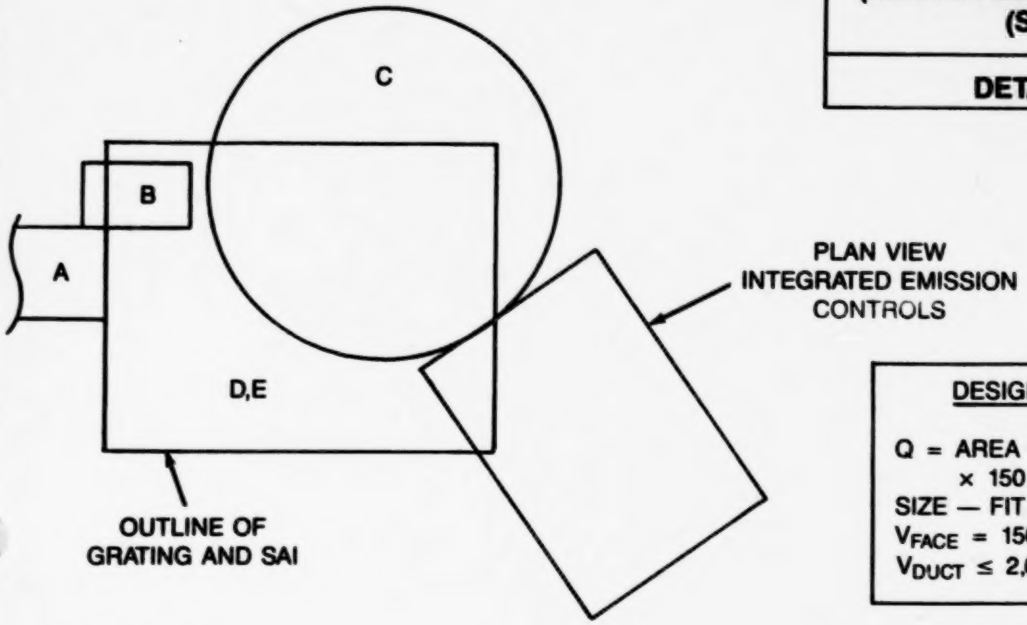

PLENUM WITH SLOT ALONG TOP
COVER OVER DUCT
4"
1"
WATER AT BOTTOM


GRATING 50% OPEN
DUCT
12"
COVER OVER SLOT
PLENUM W/ SLOT

DESIGN CRITERIA

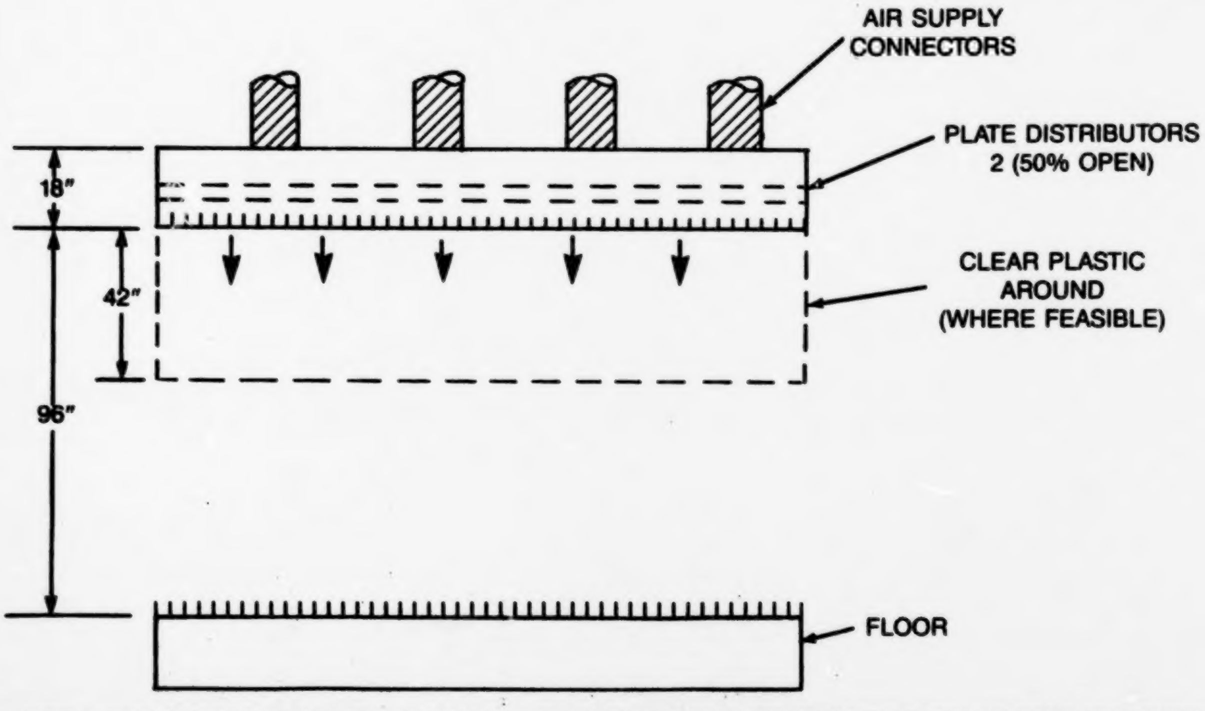
$V_T \geq 4{,}500$ fpm
Q = 100 fpm/SQ FT OF OPEN GRATING
he = 4 VP_{DUCT}
V_{SLOT} = 2000 fpm
V_{PLENUM} = 1000 fpm

INTEGRATED CONTROLS
PLATE TAKE-OFF
SUPPLIED AIR ISLAND (ABOVE FLOOR GRATING) (SAI)
DETAIL E


C
B
A
D,E
PLAN VIEW
INTEGRATED EMISSION
CONTROLS
OUTLINE OF
GRATING AND SAI

DESIGN CRITERIA

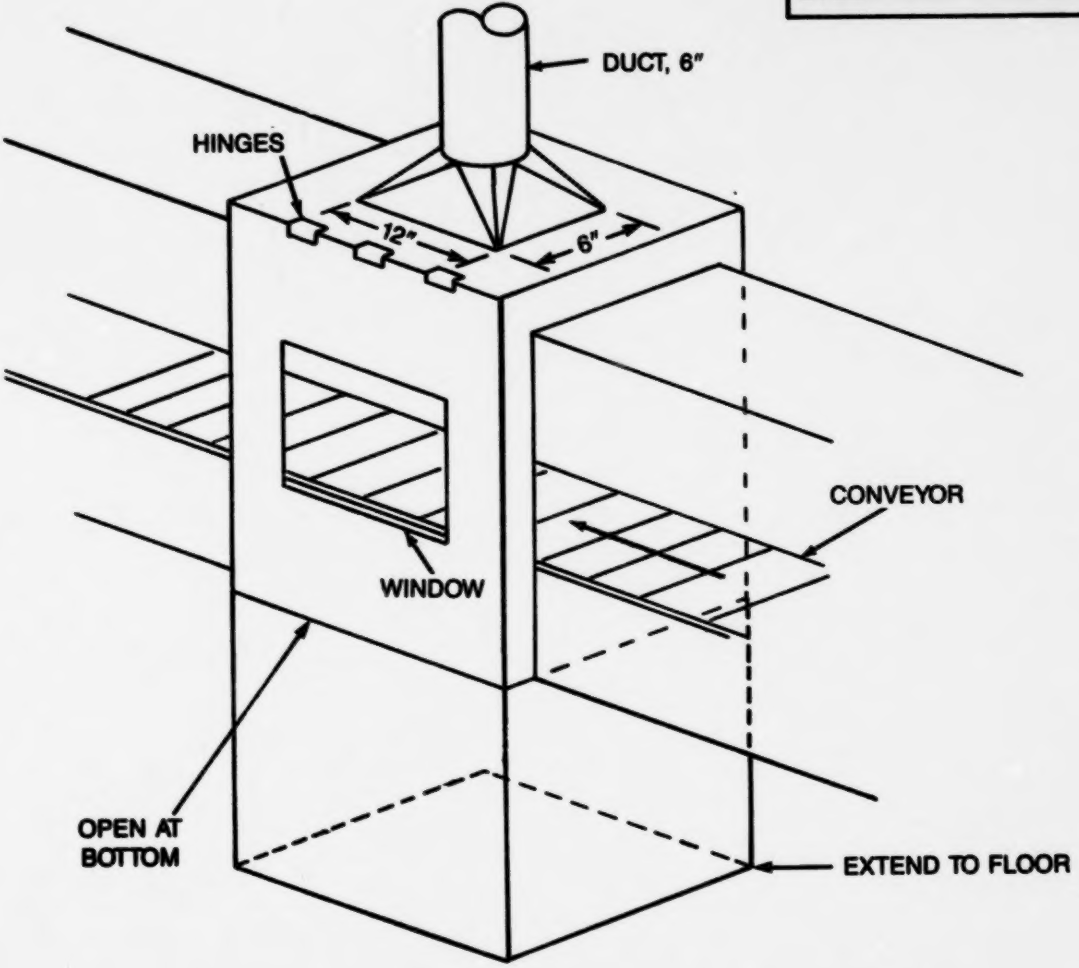
Q = AREA OF SAI (FT^2)
× 150
SIZE — FIT TO OPERATION
V_{FACE} = 150 fpm
$V_{DUCT} \leq$ 2,000 fpm


AIR SUPPLY
CONNECTORS
PLATE DISTRIBUTORS
2 (50% OPEN)
18"
42"
96"
CLEAR PLASTIC
AROUND
(WHERE FEASIBLE)
FLOOR

NOTE: SAI MUST BE PROPERLY BALANCED TO MAINTAIN A UNIFORM VELOCITY ACROSS THE FACE.

PLATE PARTING

TRANSITION HOOD BETWEEN FLASH DRIER AND TAKE OFF


DUCT, 6"
HINGES
12"
6"
WINDOW
CONVEYOR
OPEN AT BOTTOM
EXTEND TO FLOOR

DESIGN CRITERIA

$Q \cong 1200$ ctm
$V_{DUCT} \cong 6{,}000$ fpm
$SP_h = 3.4''$ W-6
$he = 0.44\ VP_{DUCT}$

or

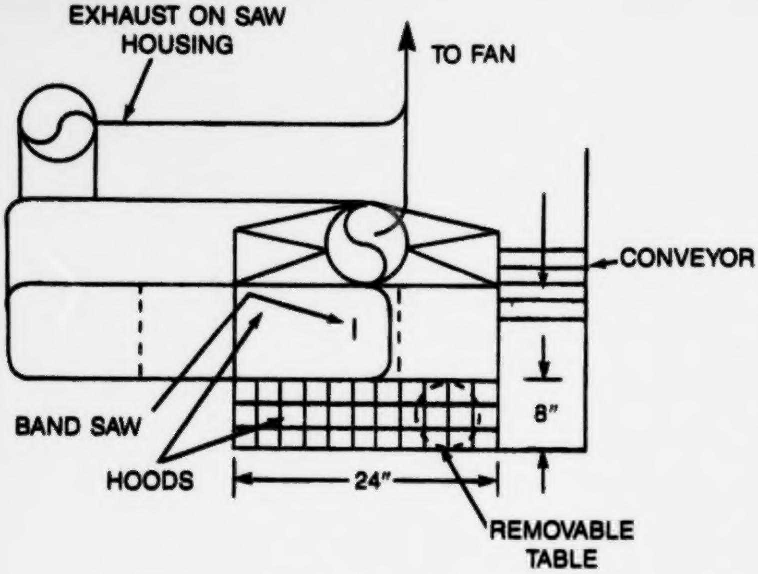
SIZE FOR Q=400 fpm
AT OPENINGS TO ROOM
(BOTTOM OF HOOD)

PARTING STATION

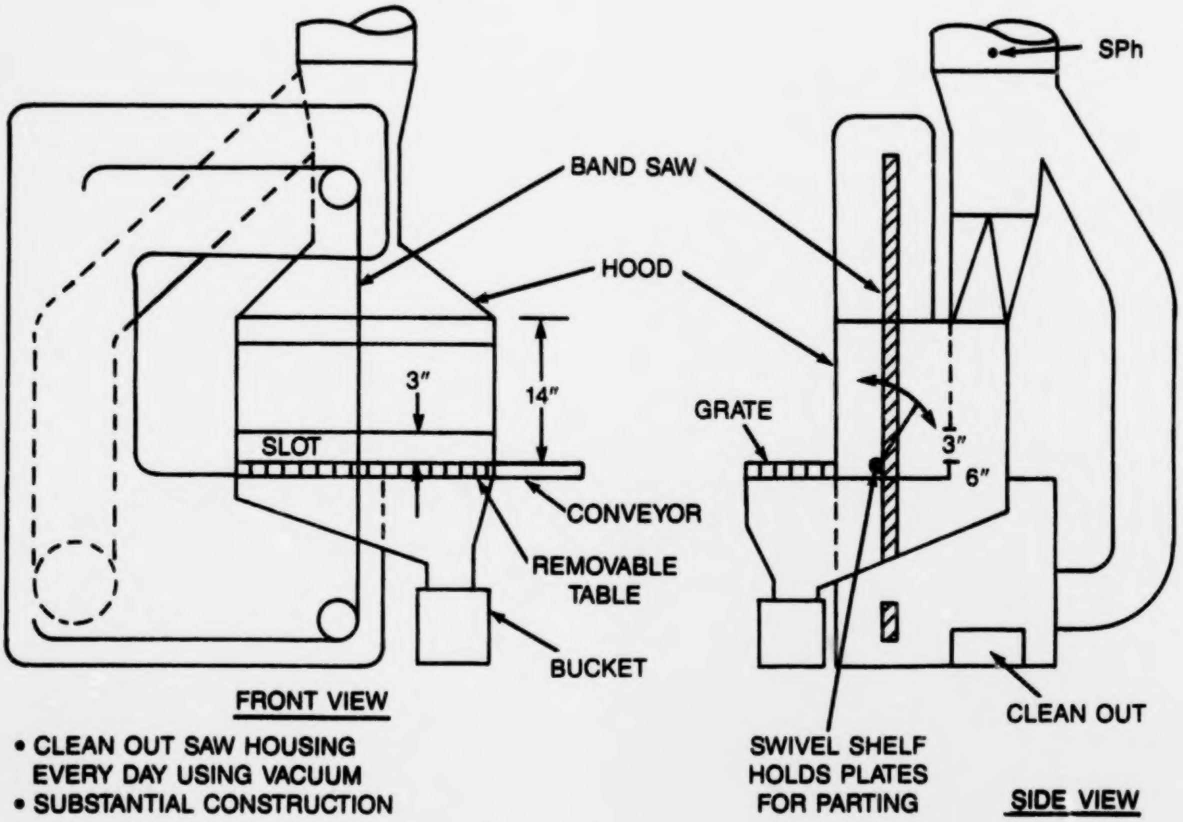
BAND SAW VENTILATION

DESIGN CRITERIA

$Q = 1{,}800$ cfm
$V_T \geq 5{,}000$ fpm
$he = 3\ VP_{DUCT}$
(IF BLAST GATES USED, DESIGN FOR $SPh \geq -4''$ w.g.)


EXHAUST ON SAW HOUSING
TO FAN
CONVEYOR
BAND SAW
HOODS
8″
24″
REMOVABLE TABLE

TOP VIEW


SPh
BAND SAW
HOOD
3″
14″
SLOT
GRATE
3″
6″
CONVEYOR
REMOVABLE TABLE
BUCKET
CLEAN OUT
SWIVEL SHELF HOLDS PLATES FOR PARTING

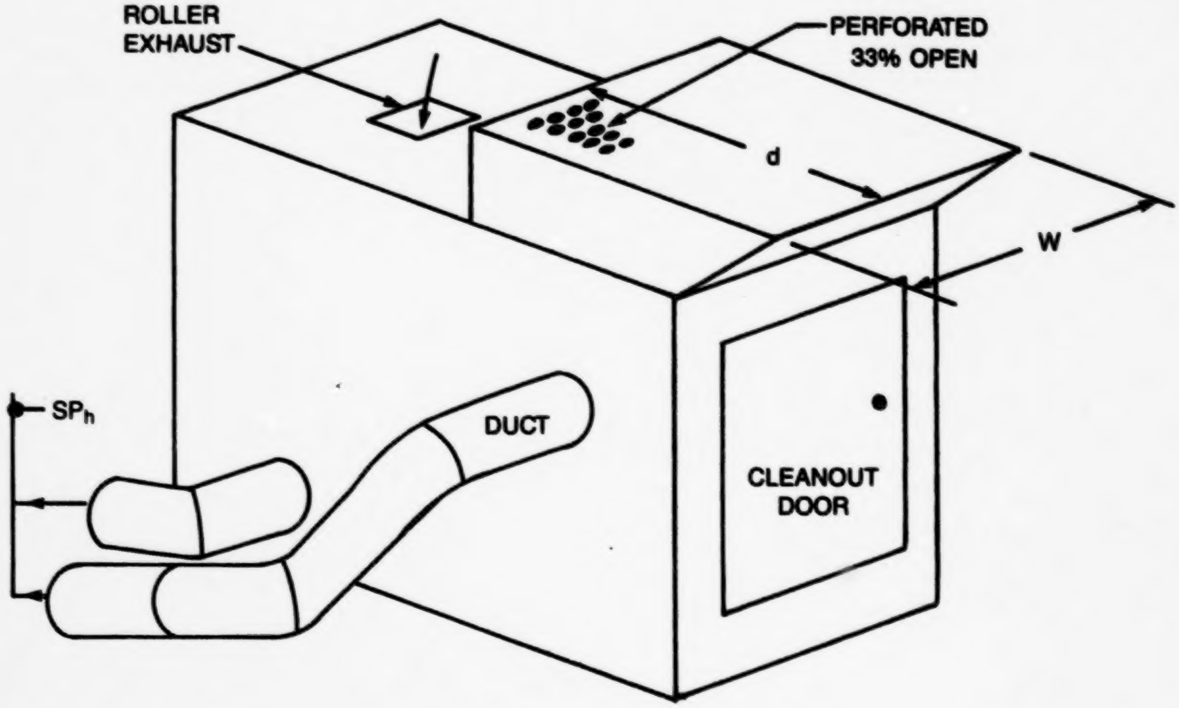
FRONT VIEW

- CLEAN OUT SAW HOUSING EVERY DAY USING VACUUM
- SUBSTANTIAL CONSTRUCTION

SIDE VIEW

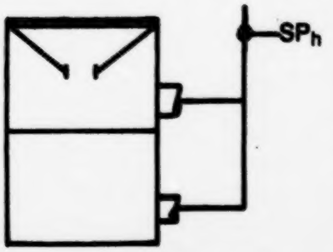
ENVELOPE ROLL STACKER TAMPING STATION

DOWNDRAFT HOOD


ROLLER EXHAUST
PERFORATED 33% OPEN
d
W
SP_h
DUCT
CLEANOUT DOOR

DESIGN CRITERIA

$Q = 400 \cdot d \cdot W + 400 \cdot$ AREA OF ROLLER EXHAUST
$V_{TRANSPORT} \geq 4{,}500$ fpm
$h_e = 6VP$



NOTE
INTERNAL
CONFIGURATION,
DUCT CONSTRUCTION

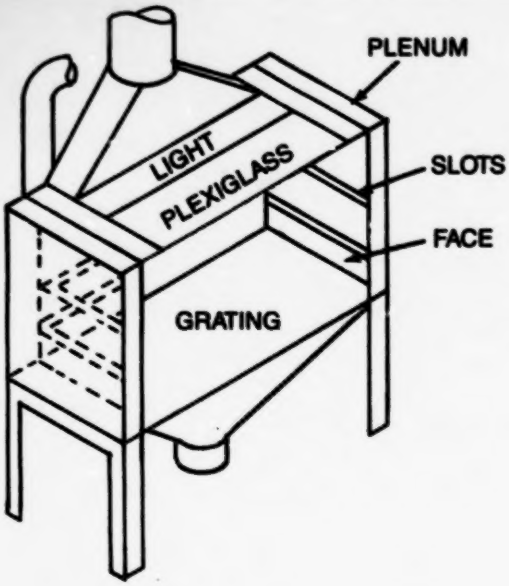
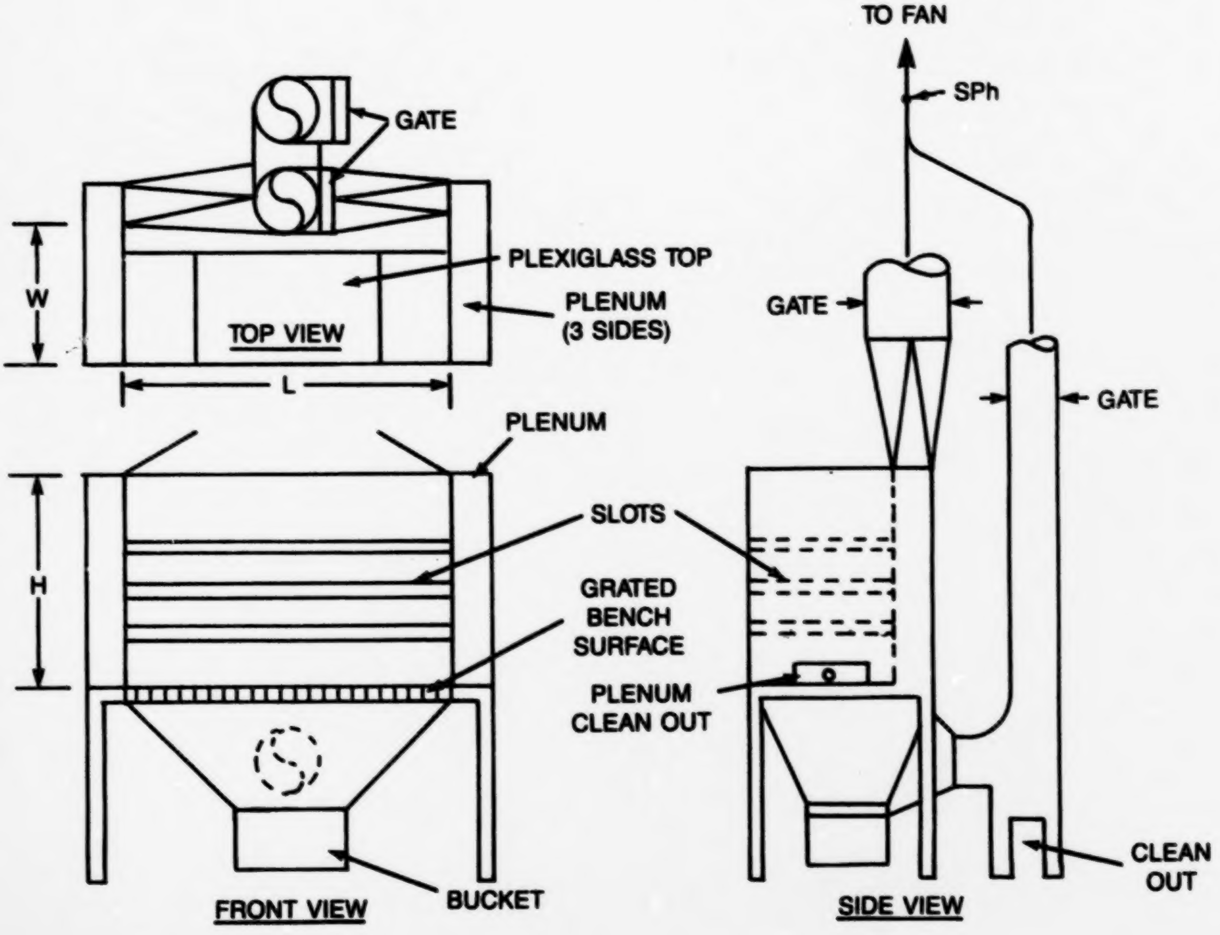

PLENUM
LIGHT
PLEXIGLASS
SLOTS
FACE
GRATING

PLATE WRAPPING STATION (INDUSTRIAL)

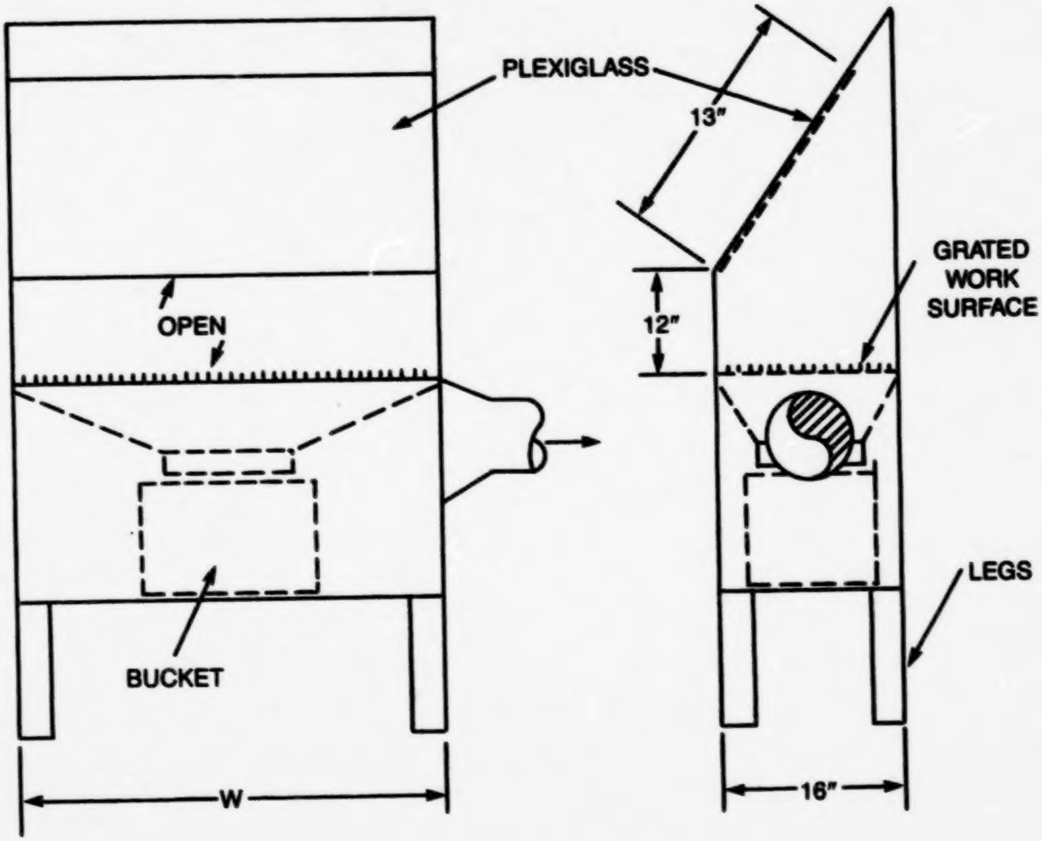
DESIGN CRITERIA

$Q = H \times L \times 300\,(\text{HOOD}) + W \times L \times 200\,(\text{GRATE})$
(TYPICAL — 4000 cfm)
$V_T \geq 4{,}500$ fpm
he = NA (USE BLAST GATES FOR BALANCING)
SPh (DESIGN) ≥ −4" W.G.
$V_{SLOT} = 2000$ fpm


TO FAN
SPh
GATE
PLEXIGLASS TOP
W
TOP VIEW
PLENUM (3 SIDES)
L
GATE
GATE
PLENUM
H
SLOTS
GRATED BENCH SURFACE
PLENUM CLEAN OUT
CLEAN OUT
FRONT VIEW
BUCKET
SIDE VIEW

STACKING TABLE

SINGLE EXHAUST BOOTH HOOD


PLEXIGLASS
OPEN
BUCKET
W
13"
12"
GRATED WORK SURFACE
LEGS
16"

DESIGN CRITERIA

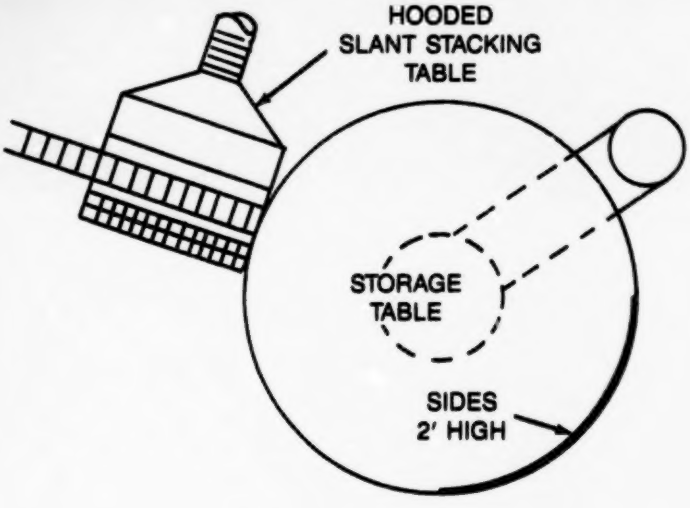
$Q = 300$ cfm/sq.ft. OPEN AREA
$V_{DUCT} \geq 4{,}500$ fpm
$h_e = 2.0\ VP_{DUCT}$
SIZE AS NEEDED; PLACE OPENING AT ELBOW LEVEL

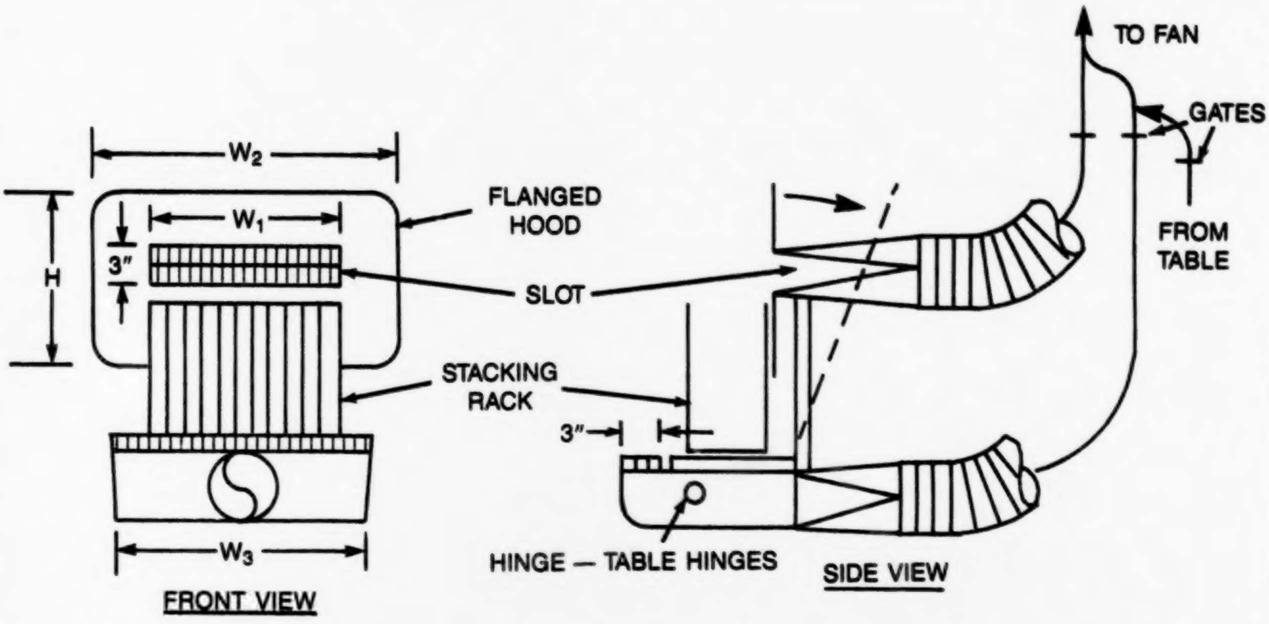
STACKING

SLANT STACKING STATION (INDUSTRIAL)

DESIGN CRITERIA

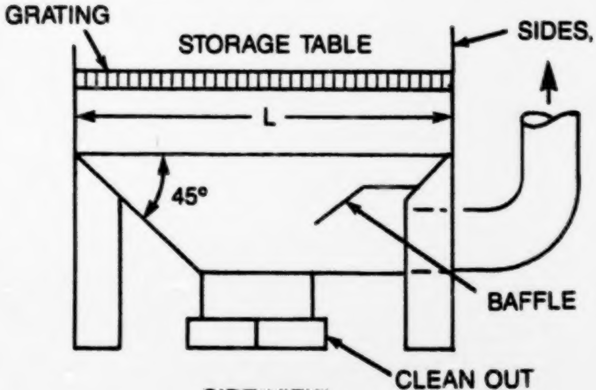
W_1 = SIZE TO JOB
$W_2 = W_1 + 1'$
H = SIZE TO JOB
$Q = 500 \times W_1 + 500 \times W_3$, cfm
$V_f \cong 2000$ fpm
$V_T \geq 4{,}500$ fpm
he = NA (BALANCED WITH GATES)
SP_h (DESIGN) $\geq -4''$ W.G.


HOODED
SLANT STACKING
TABLE
STORAGE
TABLE
SIDES
2' HIGH


TO FAN
GATES
FROM
TABLE
W2
W1
FLANGED
HOOD
3"
H
SLOT
STACKING
RACK
3"
W3
HINGE — TABLE HINGES

FRONT VIEW

SIDE VIEW


GRATING
STORAGE TABLE
SIDES, AS FEASIBLE, HINGED; SIZE TO NEED
L
45°
BAFFLE
CLEAN OUT

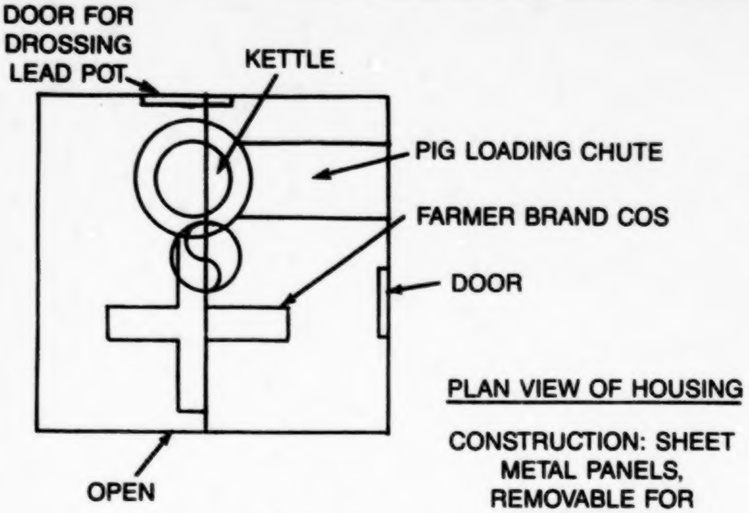
SIDE VIEW

DESIGN CRITERIA

L = SIZE TO JOB
Q = 400 cfm/SQ FT SURFACE AREA
$V_T \geq 4{,}500$ fpm

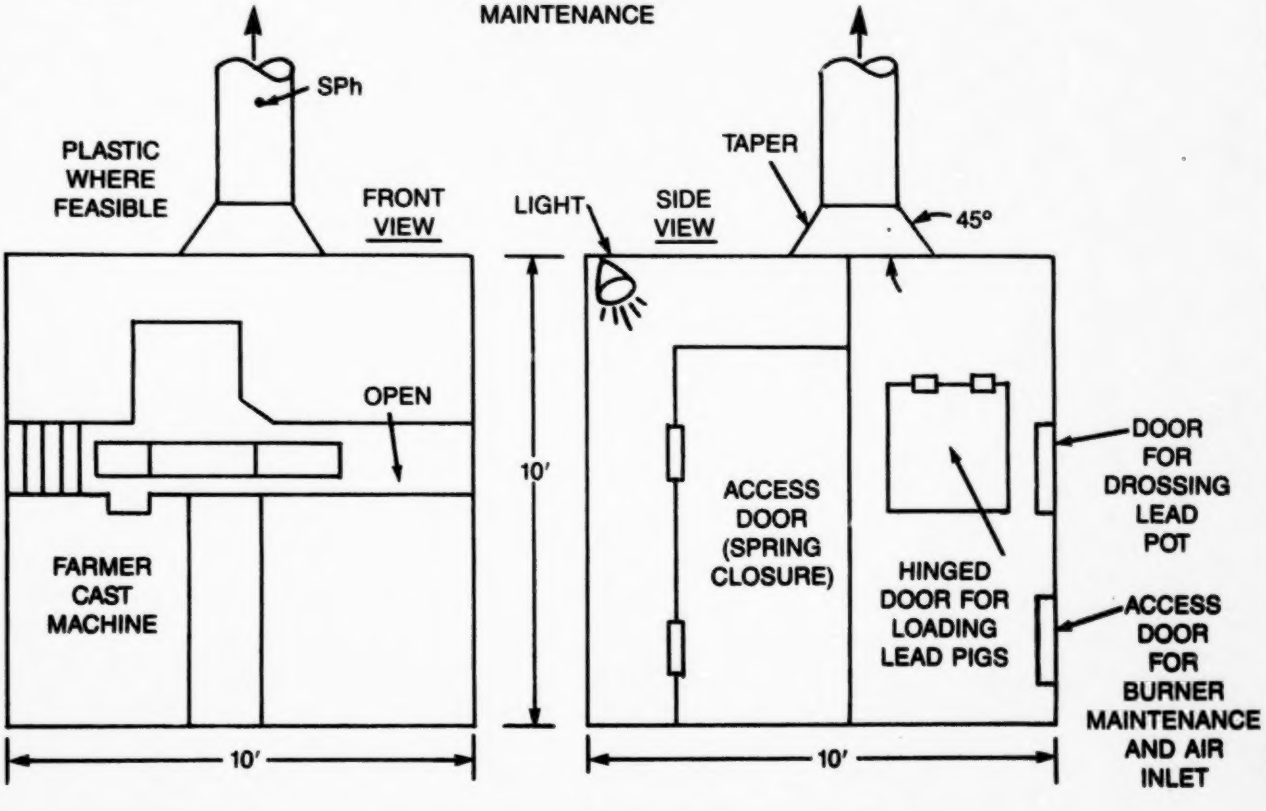
CAST ON STRAP (FARMER)

TOTAL ENCLOSURE W/ EXHAUST


DOOR FOR DROSSING LEAD POT
KETTLE
PIG LOADING CHUTE
FARMER BRAND COS
DOOR
OPEN

PLAN VIEW OF HOUSING

CONSTRUCTION: SHEET METAL PANELS, REMOVABLE FOR MAINTENANCE

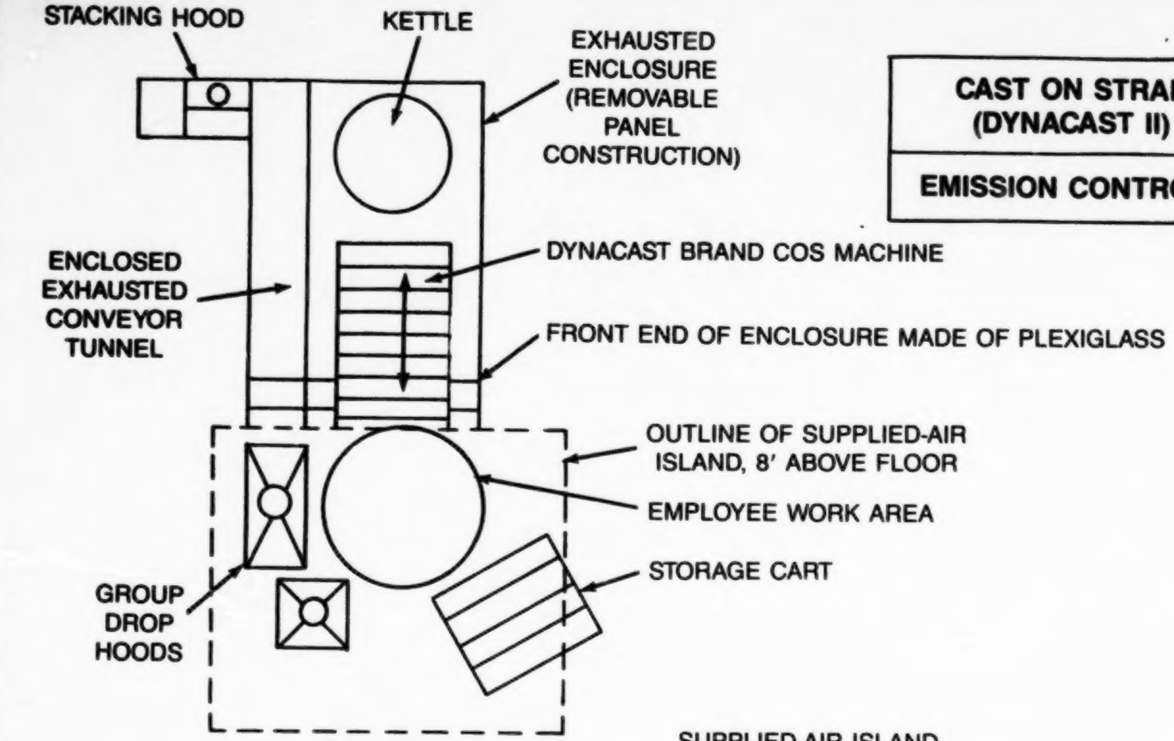

SPh
PLASTIC WHERE FEASIBLE
FRONT VIEW
OPEN
FARMER CAST MACHINE
10′
10′
LIGHT
SIDE VIEW
TAPER
45°
ACCESS DOOR (SPRING CLOSURE)
HINGED DOOR FOR LOADING LEAD PIGS
DOOR FOR DROSSING LEAD POT
ACCESS DOOR FOR BURNER MAINTENANCE AND AIR INLET
10′

DESIGN CRITERIA

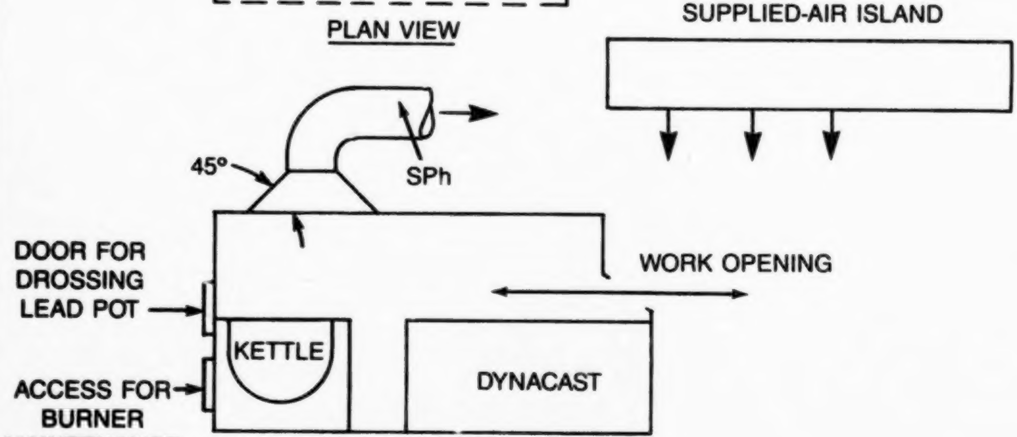
Q = 1000 ctm + 400 ctm/SQ FT OPENINGS TO ENCLOSURE
(TYPICALLY ≅ 8000 ctm)
SIZE = TO NEED
$V_T \geq 4000$ fpm
he = 0.25 VP_{DUCT}

CAST ON STRAP (DYNACAST II)

EMISSION CONTROLS


STACKING HOOD
KETTLE
EXHAUSTED ENCLOSURE (REMOVABLE PANEL CONSTRUCTION)
ENCLOSED EXHAUSTED CONVEYOR TUNNEL
DYNACAST BRAND COS MACHINE
FRONT END OF ENCLOSURE MADE OF PLEXIGLASS
OUTLINE OF SUPPLIED-AIR ISLAND, 8′ ABOVE FLOOR
EMPLOYEE WORK AREA
STORAGE CART
GROUP DROP HOODS

PLAN VIEW


SUPPLIED-AIR ISLAND
45°
SPh
WORK OPENING
DOOR FOR DROSSING LEAD POT
KETTLE
DYNACAST
ACCESS FOR BURNER MAINTENANCE

SIDE VIEW

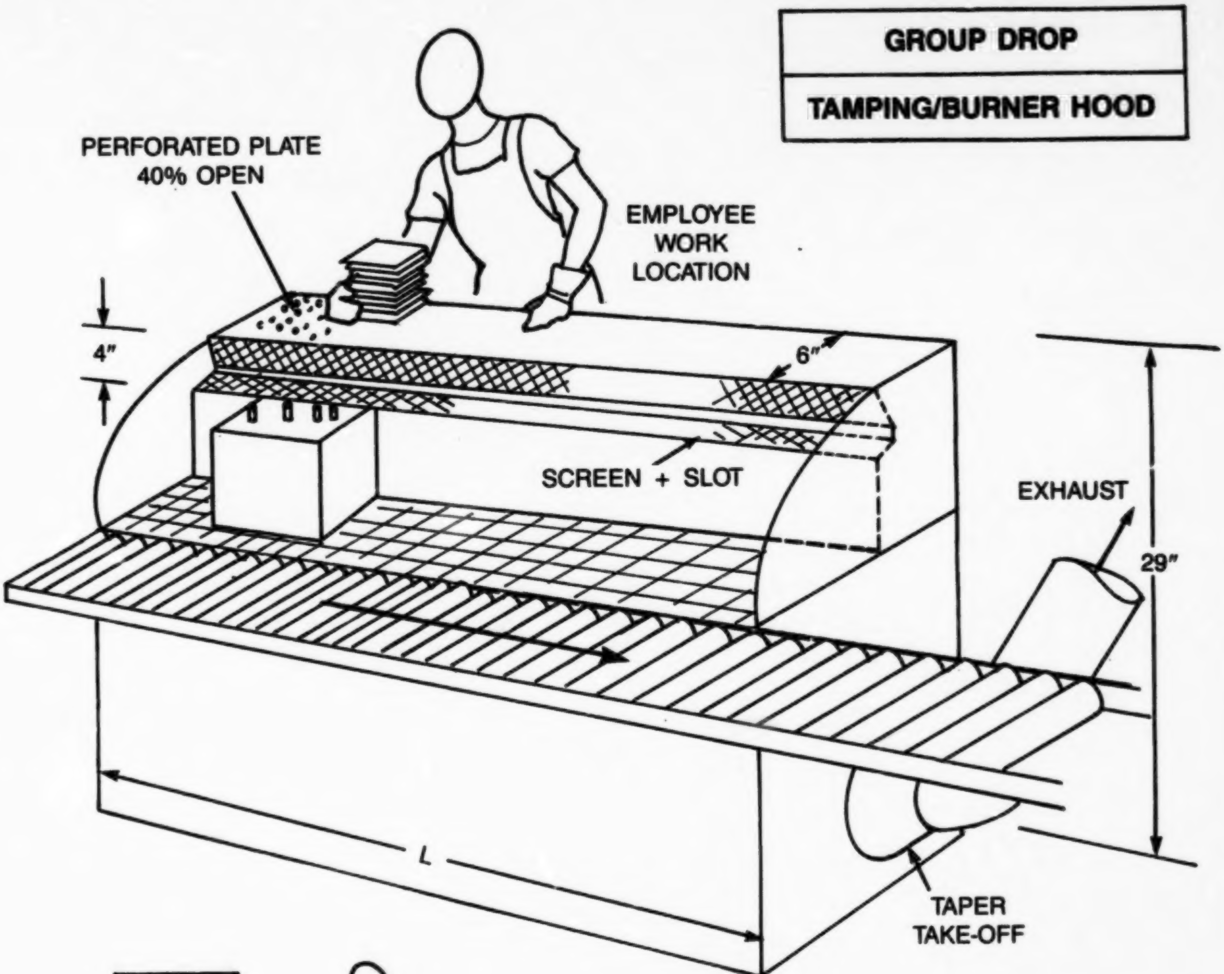
EXHAUSTED ENCLOSURE
(SEE OTHER SHEETS FOR
TYPICAL HOOD DESIGN
FOR STACKING, GROUP DROP,
SUPPLIED-AIR ISLANDS)

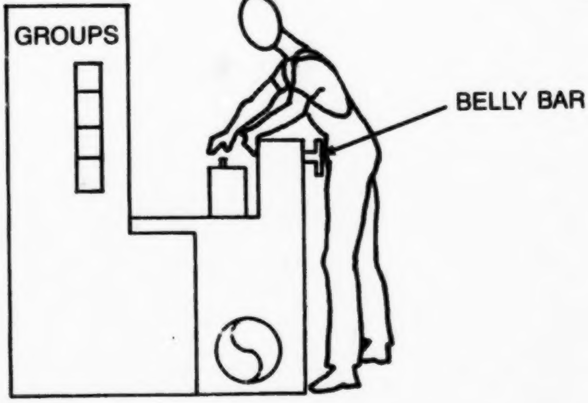
DESIGN CRITERIA

SIZE = TO NEED
(TYPICAL = 8′ × 10′ × 8′ HIGH)
Q = 1000 + 400 cfm/SQ FT OF OPEN SPACE
(TYPICAL = 3000 cfm) INTO ENCLOSURE
V_T = 4,000 fpm
he = 2 VP

GROUP DROP

TAMPING/BURNER HOOD


PERFORATED PLATE
40% OPEN
EMPLOYEE
WORK
LOCATION
4″
6″
SCREEN + SLOT
EXHAUST
29″
L
TAPER
TAKE-OFF


GROUPS
BELLY BAR

NOTE: 3″ MAXIMUM DISTANCE FOR BELLY BAR. MUST CONSIDER ERGONOMIC PROBLEMS WHICH MAY OCCUR IF EMPLOYEE MUST LIFT BATTERIES FROM A FURTHER DISTANCE.

DESIGN CRITERIA

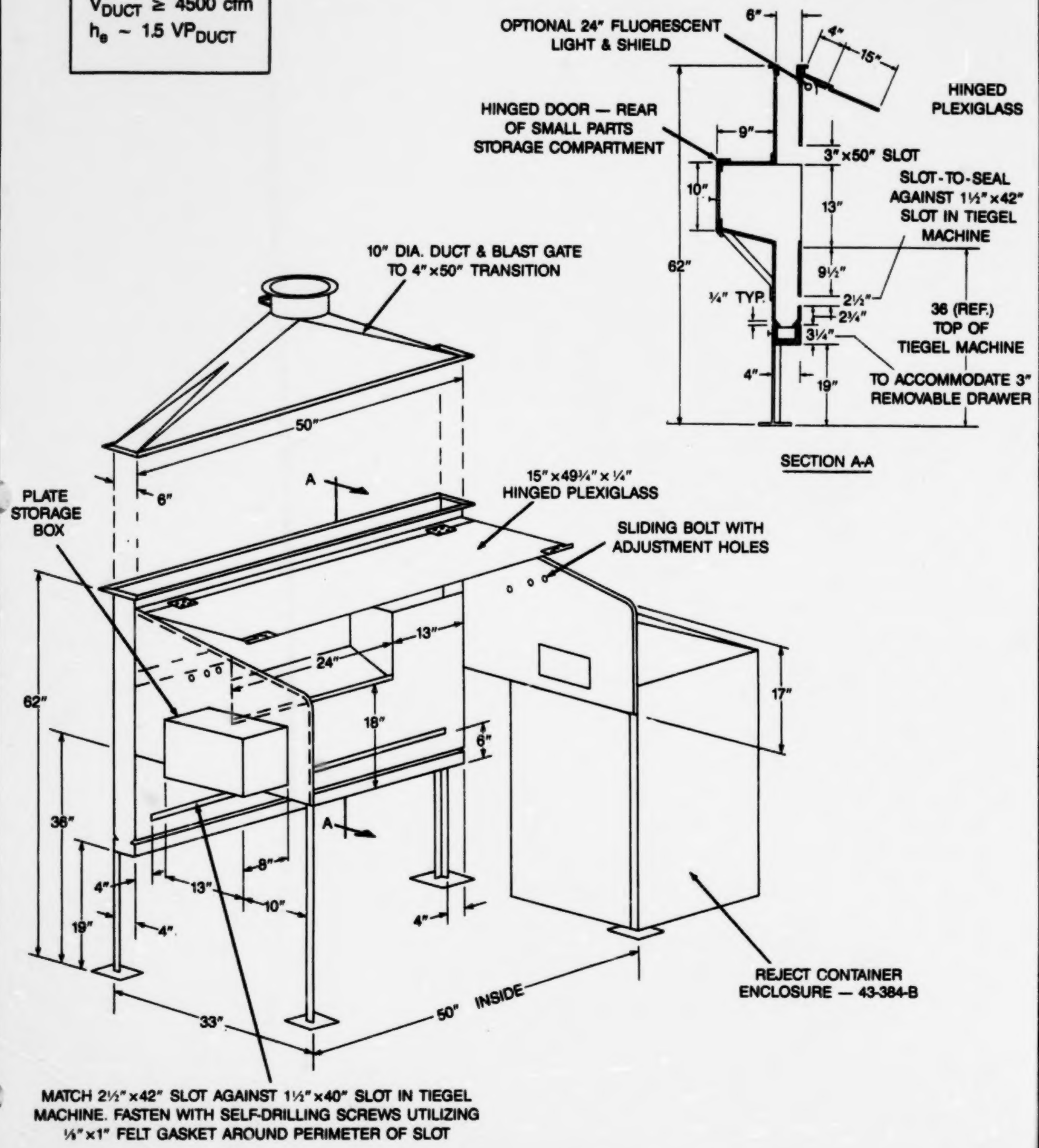
$Q = 650 \cdot L$ cfm
$V_{SLOT} = 2000$ fpm
$V_{TRANSPORT} \geq 5{,}000$ fpm
$h_e = 2.2\ VP_{DUCT}$

TIEGEL MACHINE

ENCLOSURE ASSEMBLY

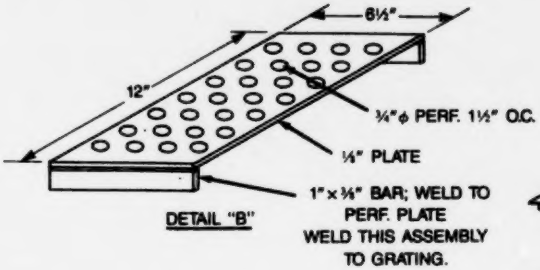
DESIGN CRITERIA

$Q = 6000$ cfm
$V_{DUCT} \geq 4500$ cfm
$h_e \sim 1.5\ VP_{DUCT}$

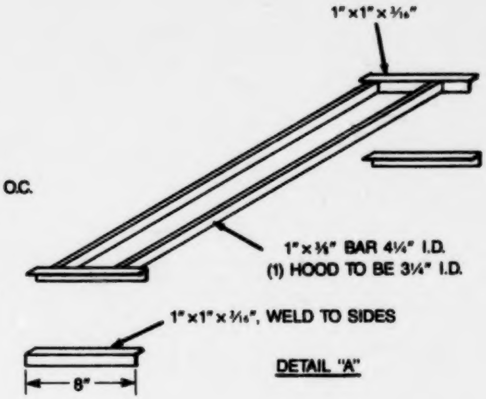

OPTIONAL 24" FLUORESCENT LIGHT & SHIELD
6"
4"
15"
HINGED PLEXIGLASS
HINGED DOOR — REAR OF SMALL PARTS STORAGE COMPARTMENT
9"
3"×50" SLOT
SLOT-TO-SEAL AGAINST 1½"×42" SLOT IN TIEGEL MACHINE
10"
13"
62"
9½"
¼" TYP.
2½"
2¼"
3¼"
36 (REF.) TOP OF TIEGEL MACHINE
4"
19"
TO ACCOMMODATE 3" REMOVABLE DRAWER
SECTION A-A
10" DIA. DUCT & BLAST GATE TO 4"×50" TRANSITION
50"
6"
A
15"×49¾"×¼" HINGED PLEXIGLASS
SLIDING BOLT WITH ADJUSTMENT HOLES
PLATE STORAGE BOX
13"
24"
18"
6"
17"
62"
36"
A
8"
4"
13"
10"
19"
4"
4"
33"
50" INSIDE
REJECT CONTAINER ENCLOSURE — 43-384-B
MATCH 2½"×42" SLOT AGAINST 1½"×40" SLOT IN TIEGEL MACHINE. FASTEN WITH SELF-DRILLING SCREWS UTILIZING ⅛"×1" FELT GASKET AROUND PERIMETER OF SLOT

TIEGEL ANCHOR

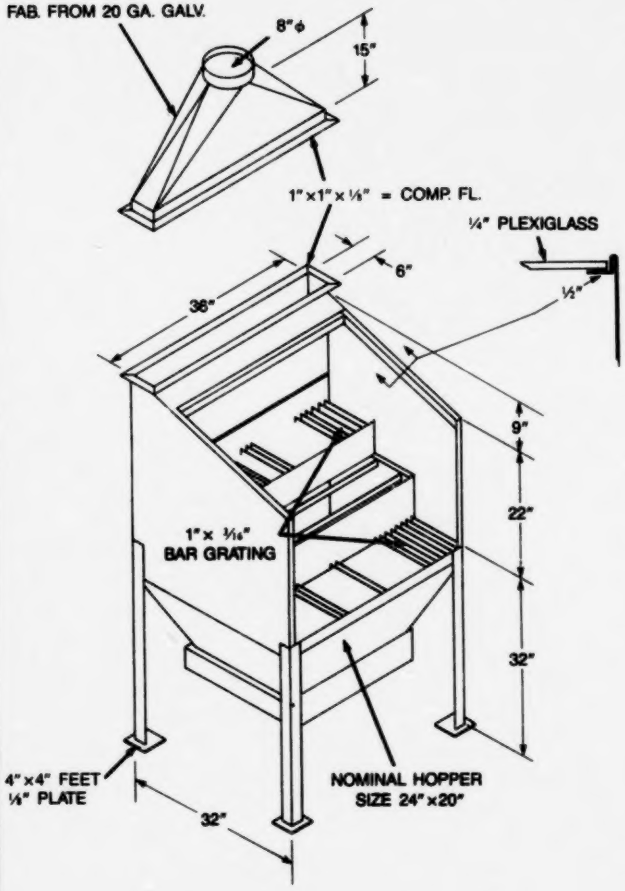
SINKING STATION


6½"
12"
¾"ϕ PERF. 1½" O.C.
¼" PLATE
1" × ⅜" BAR; WELD TO PERF. PLATE WELD THIS ASSEMBLY TO GRATING.

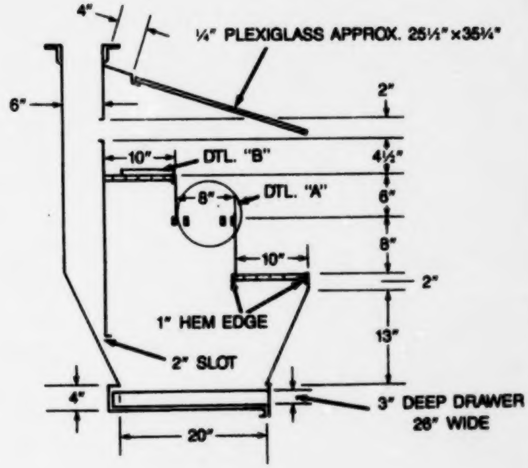
DETAIL "B"


1" × 1" × 3⁄16"
1" × ⅜" BAR 4¼" I.D.
(1) HOOD TO BE 3¼" I.D.
1" × 1" × 3⁄16", WELD TO SIDES
8"

DETAIL "A"


FAB. FROM 20 GA. GALV.
8"ϕ
15"
1" × 1" × ⅛" = COMP. FL.
¼" PLEXIGLASS
6"
36"
½"
9"
22"
1" × 3⁄16" BAR GRATING
32"
4" × 4" FEET ¼" PLATE
NOMINAL HOPPER SIZE 24" × 20"
32"

ISOMETRIC VIEW AT PRE-SINK TABLE & HOOD


4"
¼" PLEXIGLASS APPROX. 25½" × 35¼"
6"
2"
10"
DTL. "B"
4½"
8"
DTL. "A"
6"
8"
10"
2"
1" HEM EDGE
13"
2" SLOT
4"
3" DEEP DRAWER 26" WIDE
20"

NOTE: (7) SIX HOOP'S THUS REQUIRED

$Q = 2400$ cfm

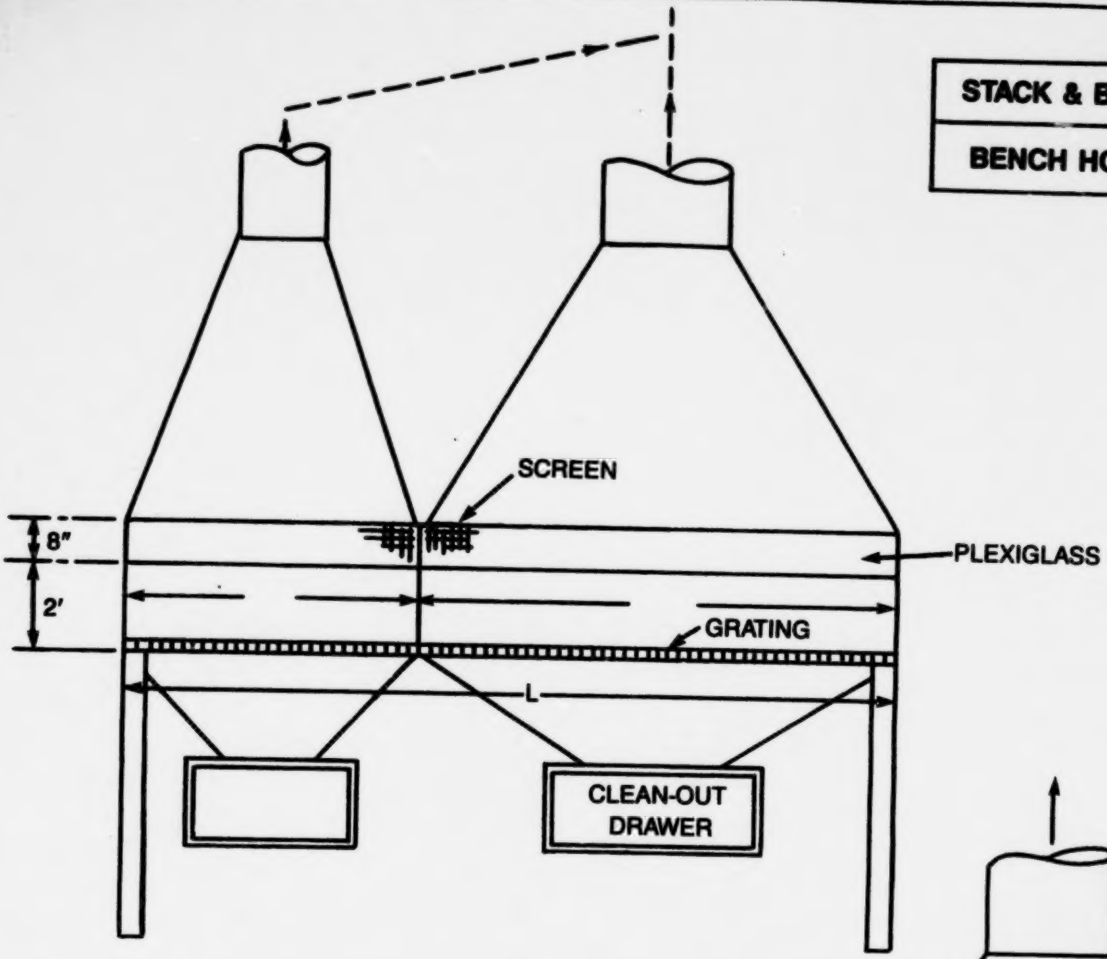
$V_{DUCT} \geq 4500$ fpm

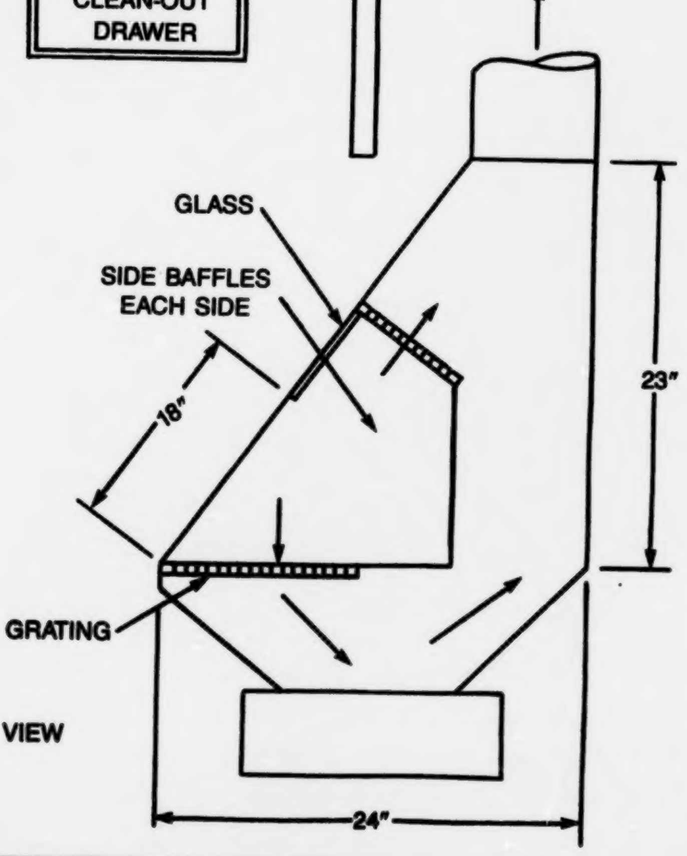
$h_e \sim 1.78\ VP_{SLOT} + 0.25\ VP_{DUCT}$

or

$\sim 0.7\ VP_{DUCT}$

STACK & BURN
BENCH HOOD


SCREEN
8"
2'
PLEXIGLASS
GRATING
L
CLEAN-OUT DRAWER


GLASS
SIDE BAFFLES EACH SIDE
18"
23"
GRATING
24"

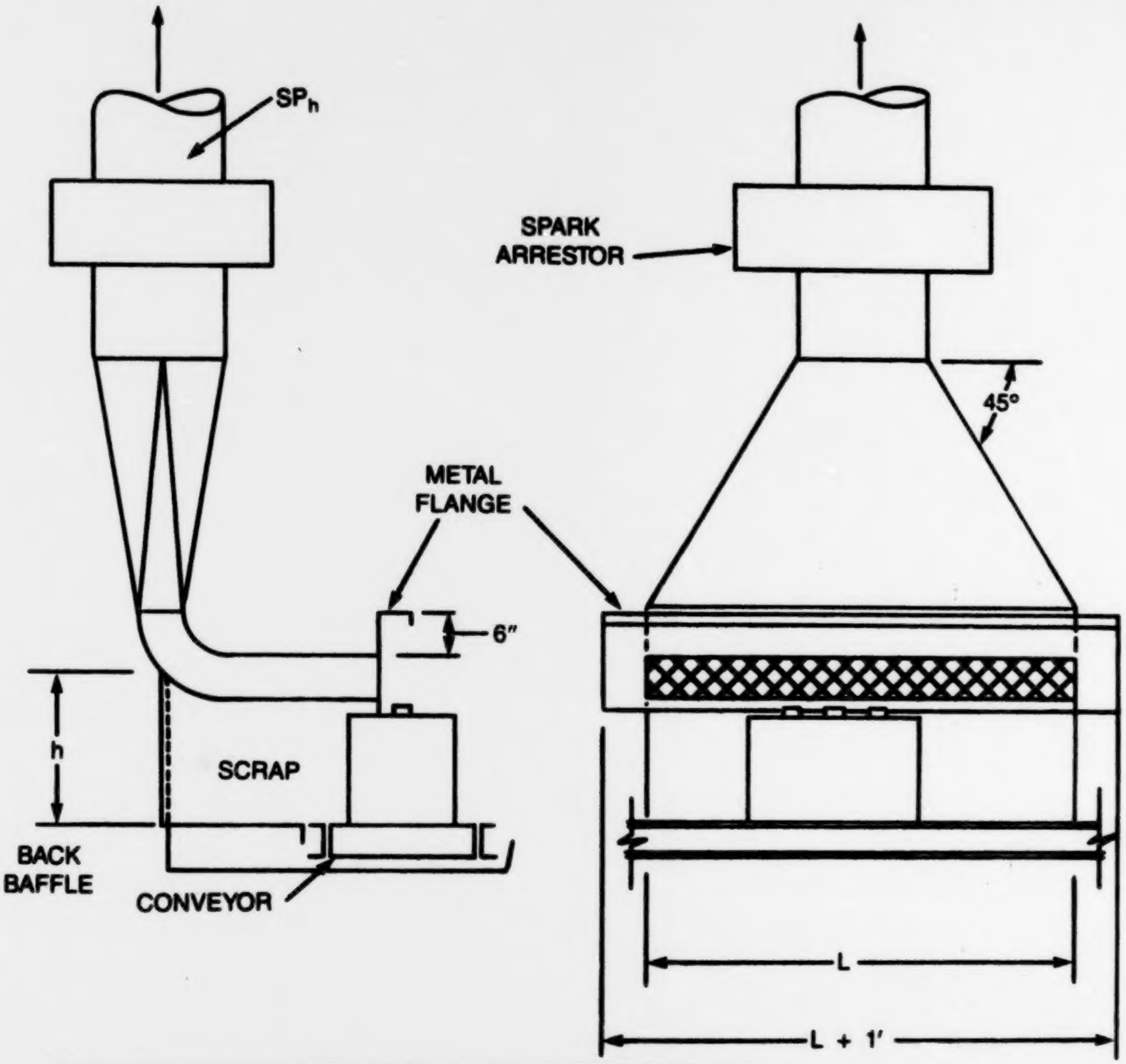
SIDE VIEW

DESIGN CRITERIA

$Q = 350 \cdot L$
$V_{TRANSPORT} \geq 4{,}500$ fpm
$h_e = 2.5\ VP_{DUCT}$

POST BURNING

BACKDRAFT HOOD


SP$_h$
SPARK ARRESTOR
45°
METAL FLANGE
6″
h
SCRAP
BACK BAFFLE
CONVEYOR
L
L + 1′

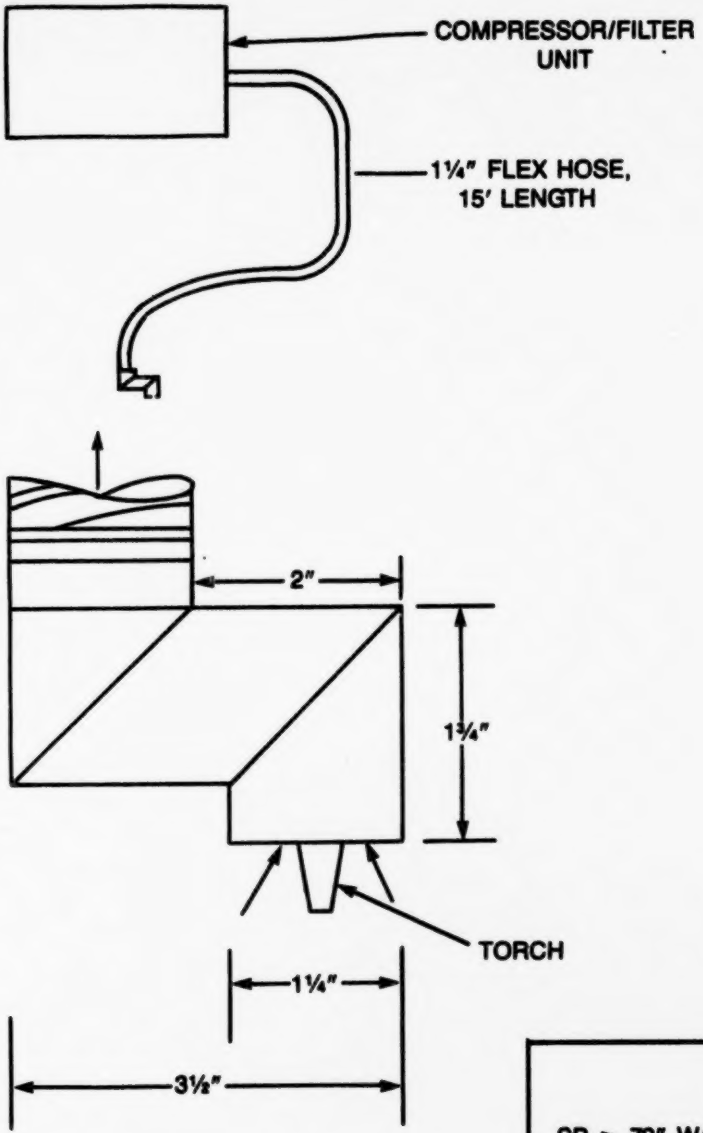
DESIGN CRITERIA

L = AS REQUIRED, FT. (USUALLY > 5′-0″)
$Q = 660 \cdot L$, cfm
$V_{TRANSPORT} \geq 4{,}000$ fpm
$V_{SLOT} = 2{,}000$ fpm
$h_e = 2.3\ VP_{SLOT} + 1.75\ VP_{DUCT}$ (INCLUDES SPARK ARR.)
h = HEIGHT OF BATTERY

NOTE — BURN TOWARD CENTER OF SLOT.
— INSTALL LARGE MESH SCREEN OVER SLOT TO PREVENT TRASH SUCH AS PAPER OR SEPARATORS FROM ENTERING.

POST BURNING

PORTABLE TOOL EXHAUST (HIGH VELOCITY/LOW VOLUME)


COMPRESSOR/FILTER UNIT
1¼" FLEX HOSE, 15' LENGTH
2"
1¾"
TORCH
1¼"
3½"

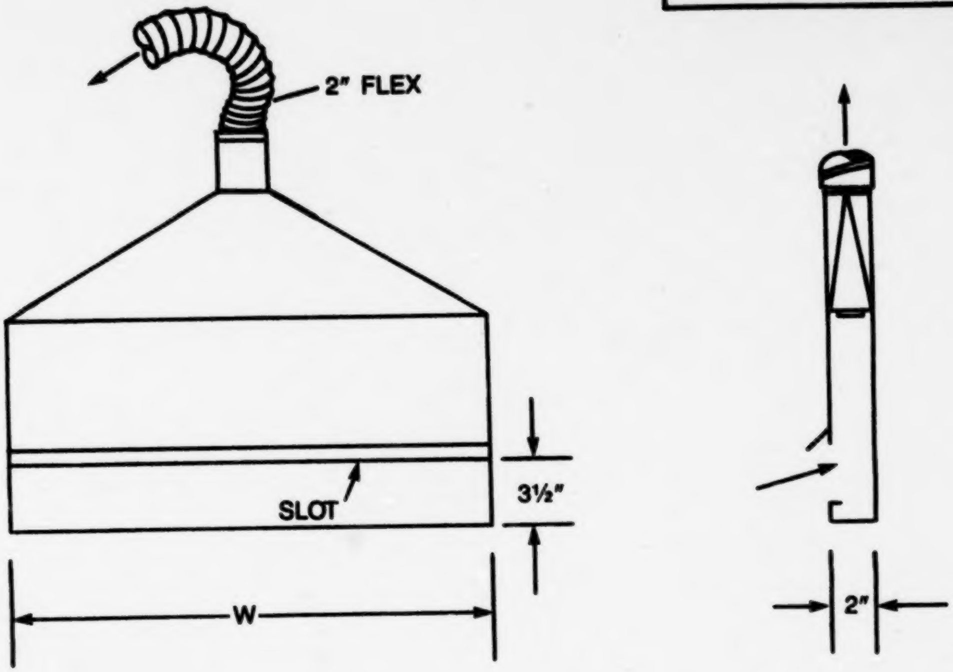
DESIGN CRITERIA

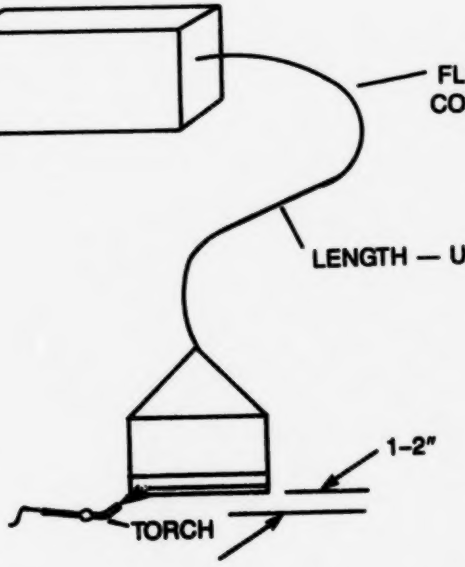
SP ≥ 72" W.G. (INLET)
Q = 40 cfm

- USE STEEL MOLD
- SOURCE MUST BE WITHIN 1" OF HOOD

POST TACKING

PORTABLE HOOD (HVLV)


2" FLEX
SLOT
3½"
W
2"


FLEX TO HIGH PRESSURE COMPRESSOR/FILTER UNIT
LENGTH — UP TO 20 FEET
1–2"
TORCH

SP ≥ 72" W.G. (INLET)

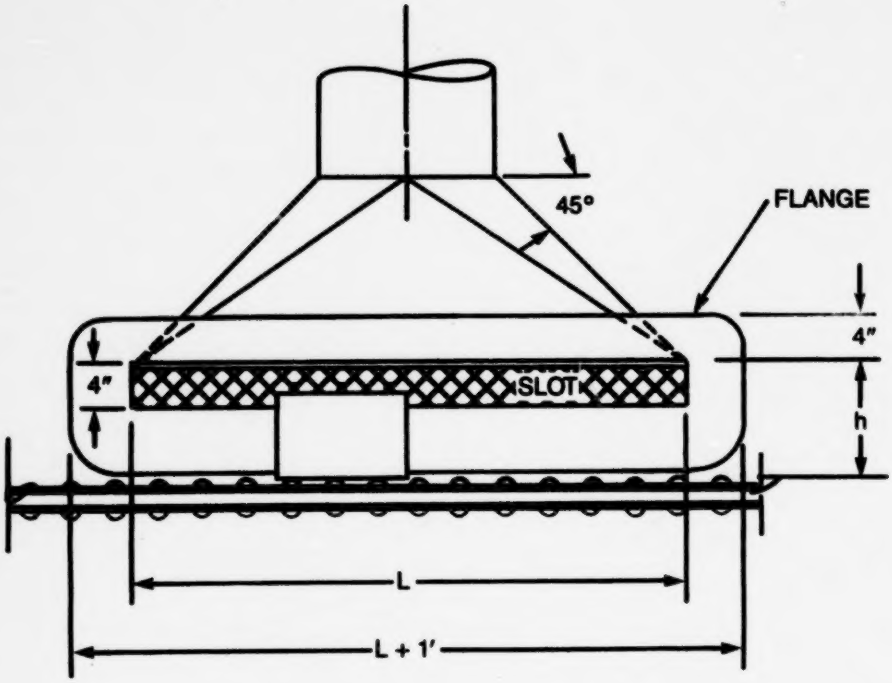
DESIGN CRITERIA

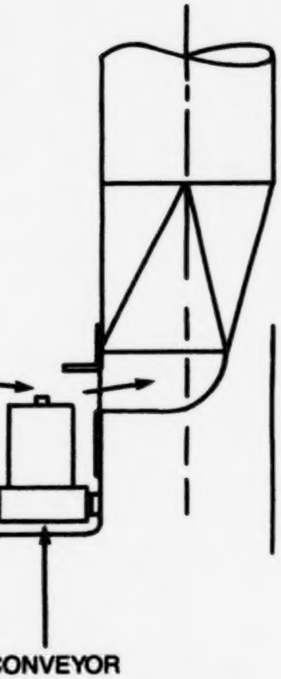
SIZE TO FIT OPERATION
$V_{SLOT} = 500$ fpm
$Q = V_{SLOT} \times$ AREA OF SLOT
$h_e = 0.35\ VP_{DUCT}$
$V_{DUCT} \geq 4{,}500$ fpm (TYPICALLY 2")

- HOOD MUST COME WITHIN INCHES OF EMISSION SOURCE.
- TORCH FLAME MUST BE DIRECTED AT SLOT.

INTERCELL BURNING

BACKDRAFT HOOD


45°
FLANGE
4"
4"
SLOT
h
L
L + 1'



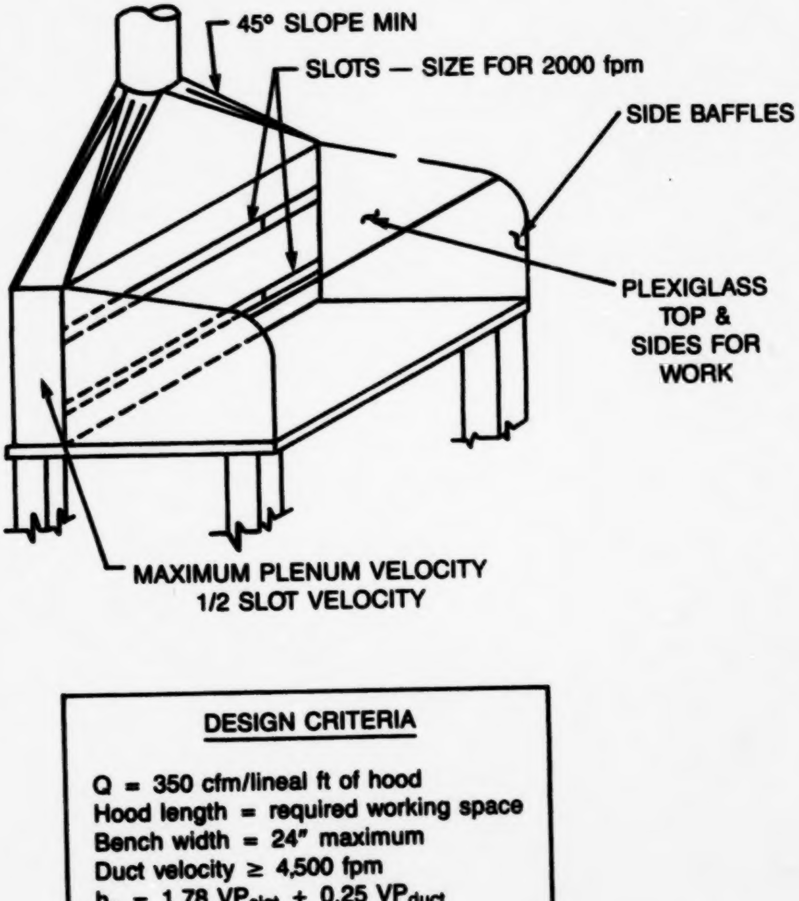
DESIGN CRITERIA

h = HEIGHT OF BATTERY + 2"
W_{SLOT} = 4"
V_{SLOT} = 2,000 fpm
$V_{DUCT} \geq$ 4,000 fpm
Q = 660 cfm • L
$h_e = 0.25\ VP_{DUCT} + 2.3\ VP_{SLOT}$

NOTE:

- — BURN WITH BATTERY AGAINST FLANGE.
- — BURN ONLY TOWARD SLOT.
- — INSTALL LARGE MESH SCREEN OVER SLOT TO KEEP TRASH OUT.

WORK BENCH
GENERAL DUTY


45° SLOPE MIN
SLOTS — SIZE FOR 2000 fpm
SIDE BAFFLES
PLEXIGLASS TOP & SIDES FOR WORK
MAXIMUM PLENUM VELOCITY 1/2 SLOT VELOCITY

DESIGN CRITERIA

Q = 350 cfm/lineal ft of hood
Hood length = required working space
Bench width = 24" maximum
Duct velocity ≥ 4,500 fpm
$h_e = 1.78\ VP_{slot} + 0.25\ VP_{duct}$

SOURCE: ADOPTED FROM ACGIH

SCRAP BARREL

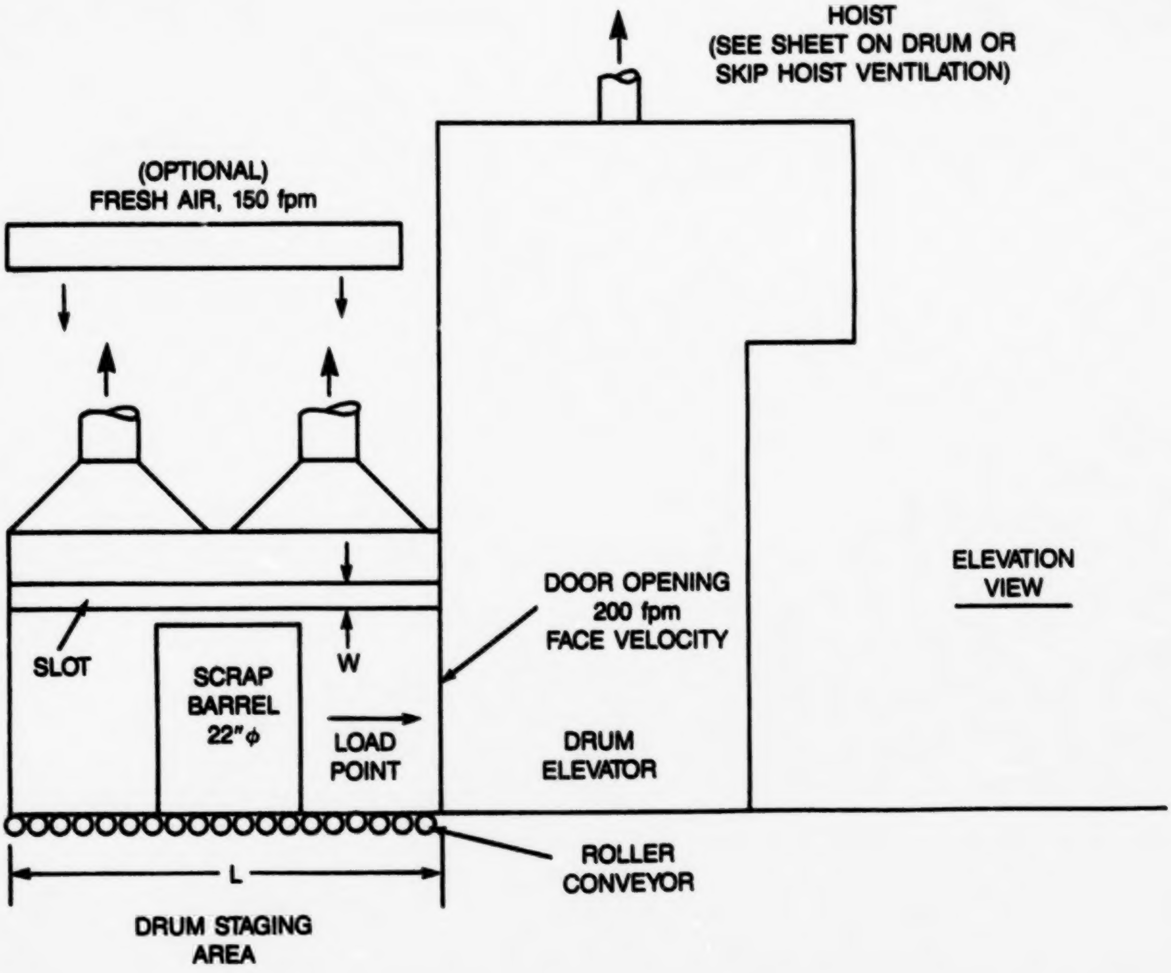
PRE-HOIST CONTROLS

$W = 0.25'$ (Typical)

$V_{SLOT} = 2000$ fpm

$Q = 2000 \cdot W \cdot L$

$h_e = 1.78\ VP_{SLOT} + 0.25\ VP_{DUCT}$

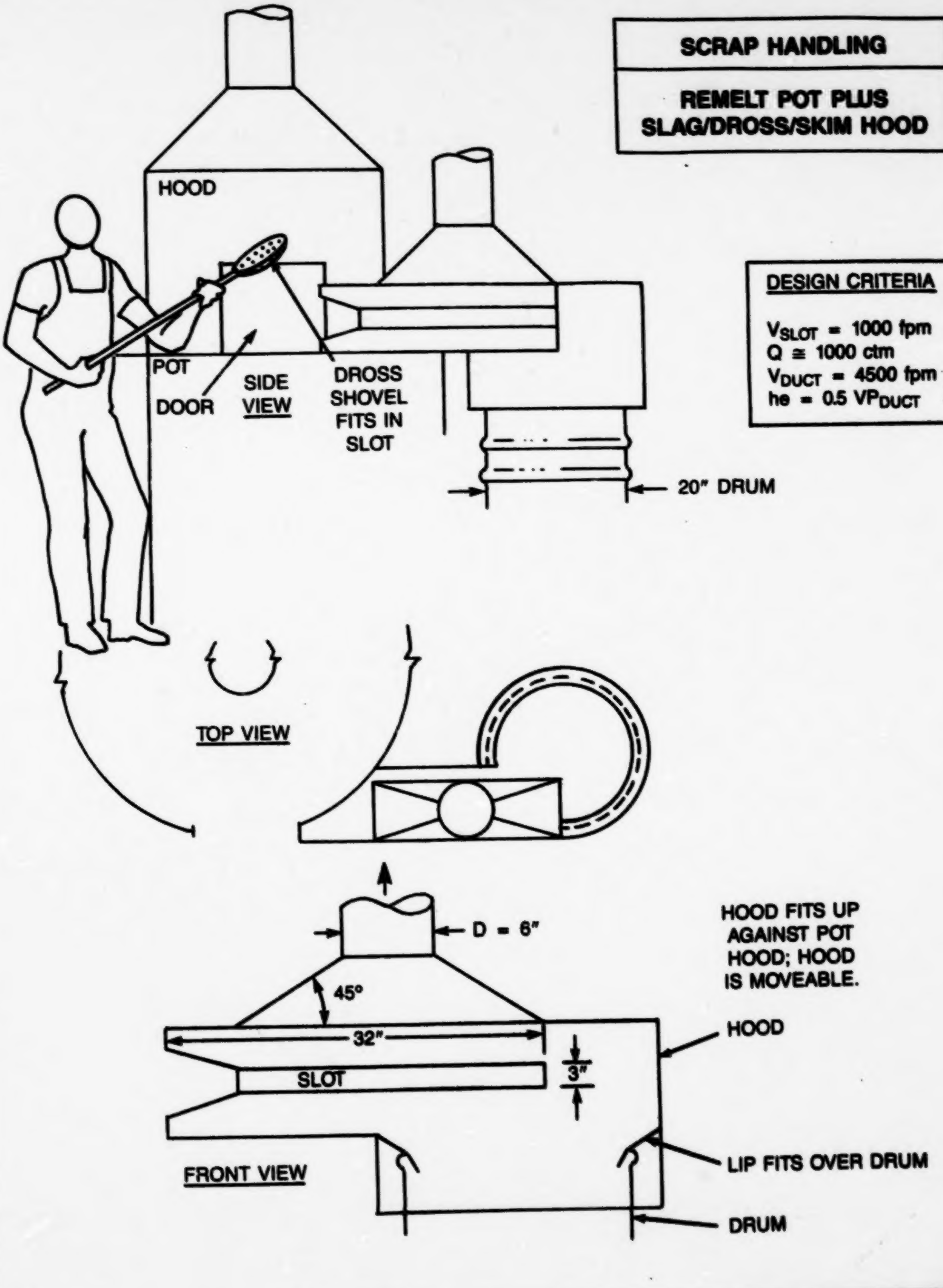

HOIST
(SEE SHEET ON DRUM OR SKIP HOIST VENTILATION)
(OPTIONAL)
FRESH AIR, 150 fpm
SLOT
W
SCRAP BARREL 22"ϕ
LOAD POINT
DOOR OPENING 200 fpm FACE VELOCITY
DRUM ELEVATOR
ELEVATION VIEW
ROLLER CONVEYOR
L
DRUM STAGING AREA

SCRAP HANDLING

REMELT POT PLUS SLAG/DROSS/SKIM HOOD

DESIGN CRITERIA

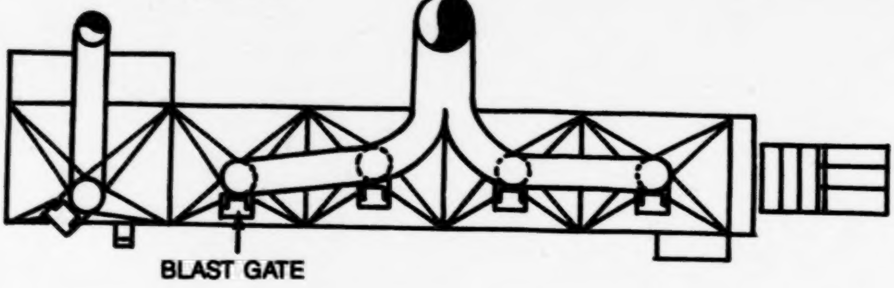
V_{SLOT} = 1000 fpm
$Q \cong$ 1000 cfm
V_{DUCT} = 4500 fpm
he = 0.5 VP_{DUCT}

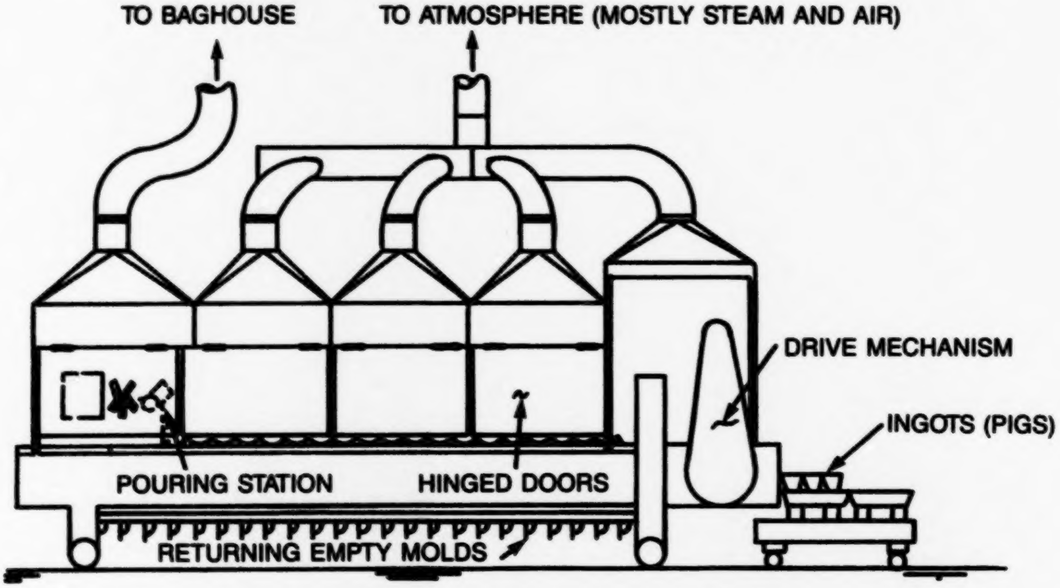

HOOD
POT
DOOR
SIDE VIEW
DROSS SHOVEL FITS IN SLOT
20" DRUM
TOP VIEW
D = 6"
45°
32"
SLOT
3"
HOOD FITS UP AGAINST POT HOOD; HOOD IS MOVEABLE.
HOOD
LIP FITS OVER DRUM
DRUM
FRONT VIEW

INGOT CASTING

LOCAL EXHAUST VENTILATION

TOP VIEW




TO BAGHOUSE
TO ATMOSPHERE (MOSTLY STEAM AND AIR)
DRIVE MECHANISM
INGOTS (PIGS)
POURING STATION
HINGED DOORS
RETURNING EMPTY MOLDS

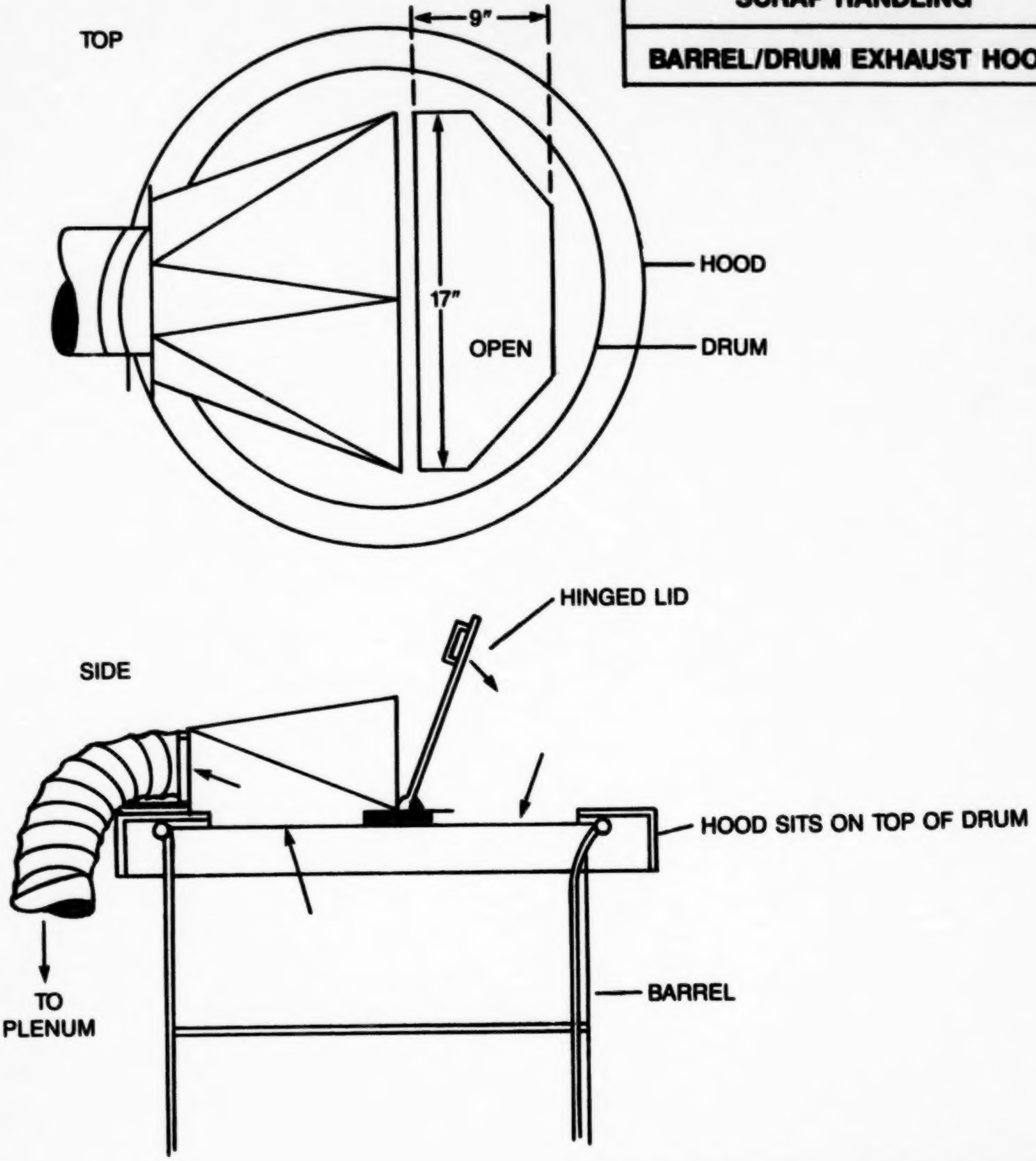
DESIGN CRITERIA

Casting Hood:
Q = 500 scfm/sq. ft. of Equipment + 100 scfm/sq. openings
$h_e = 0.5\ VP_{duct}$
$V_{transport} \geq 400$ fpm

Cooling Hood:
Q = 100 scfm/sq. ft. openings + 500 scfm per gal. H_2O used per minute
$h_e = 3.3\ VP$
$V_{duct} \geq 2000$ fpm

SCRAP HANDLING

BARREL/DRUM EXHAUST HOOD

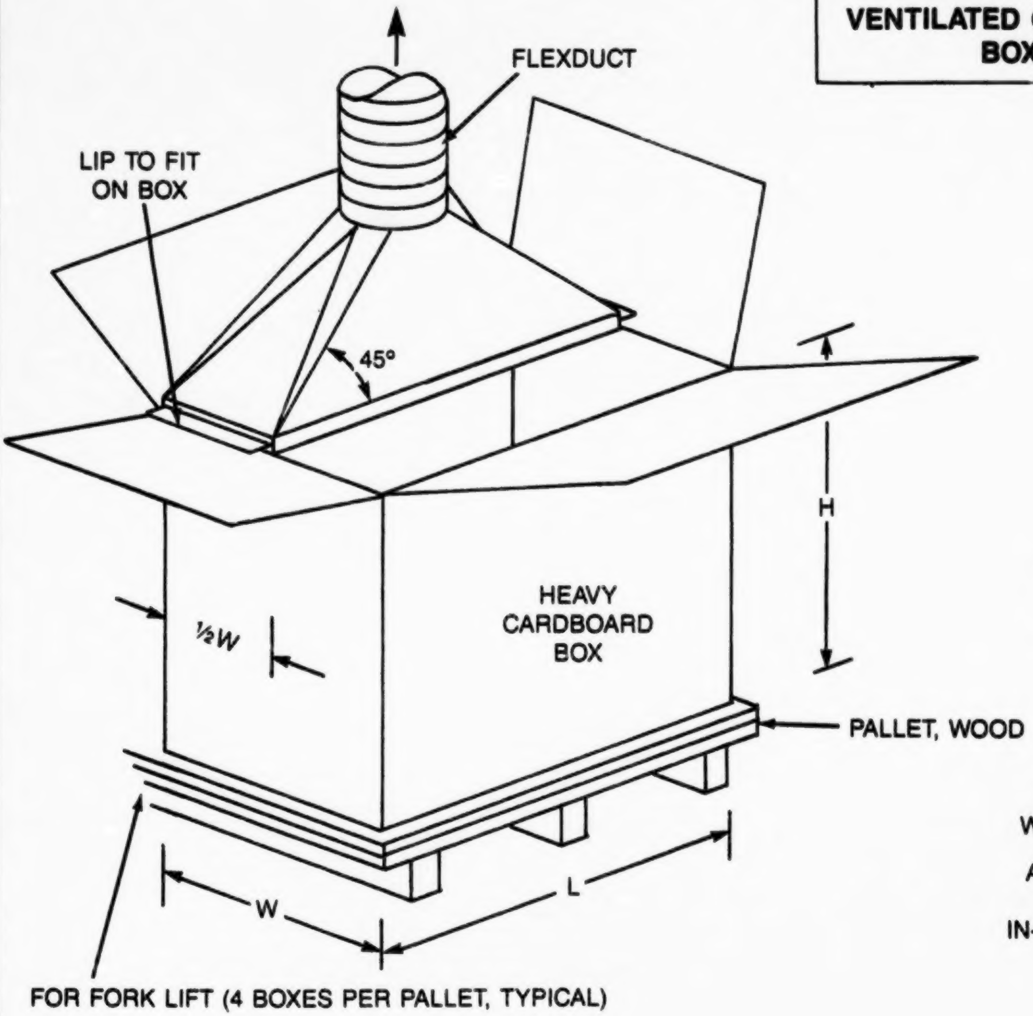

TOP
9"
17"
OPEN
HOOD
DRUM
HINGED LID
SIDE
HOOD SITS ON TOP OF DRUM
BARREL
TO PLENUM

DESIGN CRITERIA

$Q \cong 400$ acfm
$V_{DUCT} \cong 4500\text{–}5000$ fpm
$D_{DUCT} = 4''$ (FLEX) UP TO 4′ LONG
$h_e = 1.4\ VP_{DUCT}$
CONSTRUCT OF 10–12 GA STEEL; REINFORCE

SCRAP HANDLING

VENTILATED CARDBOARD BOXES


FLEXDUCT
LIP TO FIT ON BOX
45°
H
½W
HEAVY CARDBOARD BOX
PALLET, WOOD
L
W
FOR FORK LIFT (4 BOXES PER PALLET, TYPICAL)

SPECIFY
BOX TO CARRY
UP TO 500 LBS.

HOOD COVERS
½ OF OPEN
TOP

CARDBOARD —
HEAVY-DUTY,
WAX-IMPREGNATED

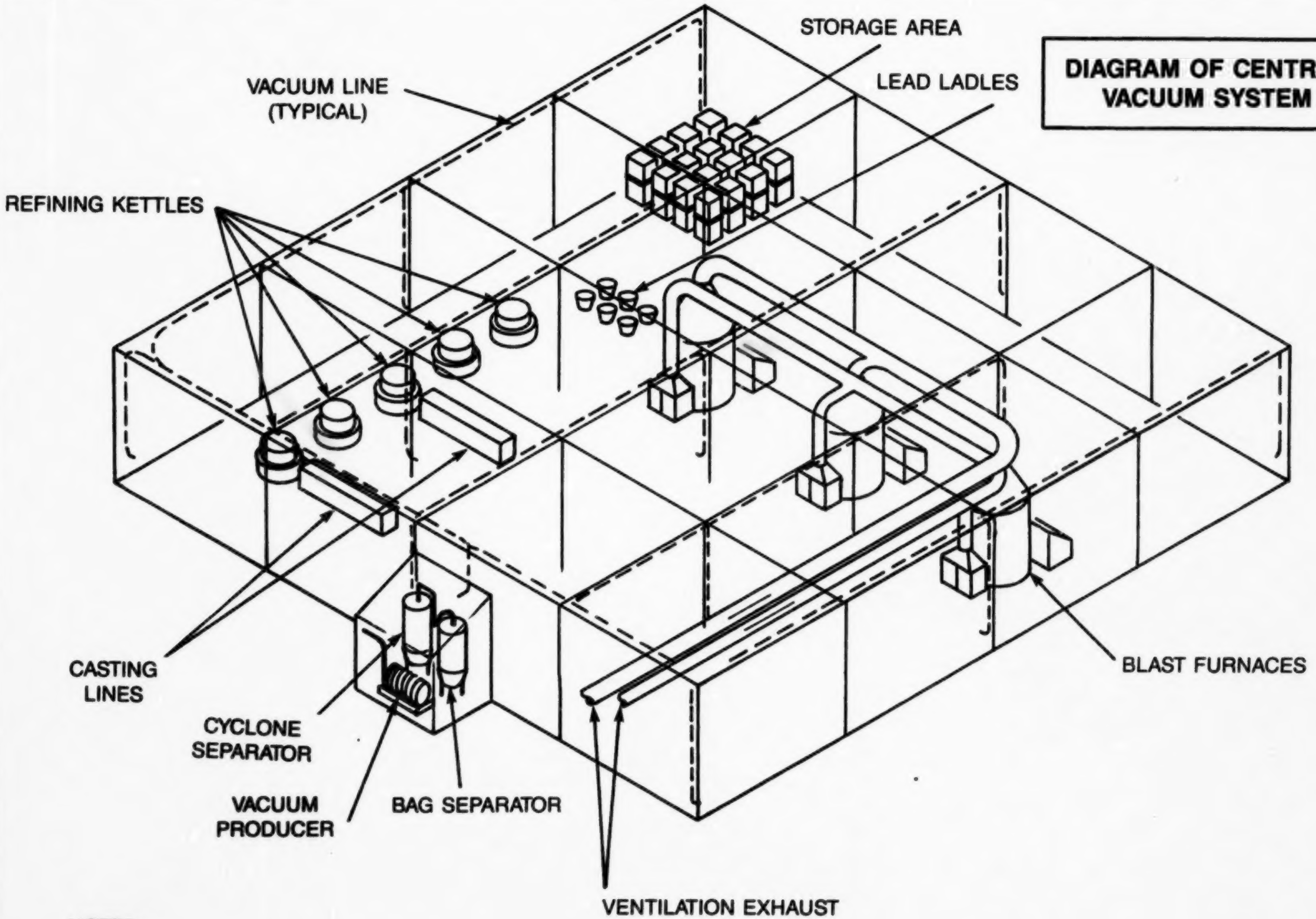
AFTER FULL, SEAL
AND SEND TO
IN-HOUSE RECYCLING
FACILITY, e.g.
SMELTER

USED FOR LEADY SCRAP, GLOVES, ETC.

DESIGN CRITERIA

SIZE FOR OPERATION — W, L, H
$Q = L \times \frac{1}{2}W \times 300$, cfm
$h_e = 0.25\ VP_{DUCT}$
$V_D \geq 4{,}500$ fpm

DIAGRAM OF CENTRAL VACUUM SYSTEM


STORAGE AREA
LEAD LADLES
VACUUM LINE (TYPICAL)
REFINING KETTLES
CASTING LINES
CYCLONE SEPARATOR
VACUUM PRODUCER
BAG SEPARATOR
VENTILATION EXHAUST
BLAST FURNACES

NOTES:

- LOCATE EXHAUST OUTSIDE.
- OVERDESIGN FOR LEAD TRANSPORT.
- PROVIDE AMPLE HOSE & ATTACHMENTS AT EACH ACCESS POINT.
- PROVIDE ACCESS POINT CLOSE TO AREAS OF HIGH DUST CONCENTRATION.

APPENDIX A
SAMPLE COMPLIANCE PLAN

ABC BATTERY MANUFACTURING, INC.
SALT LAKE CITY, UT
LEAD COMPLIANCE PROGRAM
SEPTEMBER 5, 1985

INTRODUCTION

In accordance with the requirements set forth by the Occupational Safety and Health Administration for development of Cooperative Assessment Programs, a plant-wide survey for lead has been conducted with personal samples obtained for each employee exposed to lead.

The results of this survey indicate that the following operations have lead exposures in excess of 50 ug/M^3:

(1) Paste Mixing
(2) Plate Pasting
(3) Dynacast

I. PROCESS DESCRIPTION

A. Paste Mixing: Lead oxide, expander, sulfuric acid and water are mixed to produce a paste which properly supported by a lead grid becomes the active material in a lead/acid storage battery plate.

Equipment used: #2 Simpson Mixer, drum elevator and dumper, and electric monorail and hoist.

Material processed: oxide in drums, lead oxide expander, sulfuric acid

Controls: (a) local exhaust for removing and replacing drum covers, (b) negative pressure on drum dumper and mixer

Crew size: one operator

Safety equipment: respirator, goggles, coveralls

Job responsibilities)
Operating procedures) See Work Practices Section
Maintenance practices)

B. Plate Pasting: Lead or lead alloy grids are impregnated with lead oxide paste from paste mixing. Plates are run through a drying oven to remove enough moisture so that they won't stick together during curing and storage.

Equipment used: MAC paster and plate drying oven

Material processed: Paste and grids

Controls: Local exhaust on oven take-off conveyor

Crew size: 2

Safety equipment: respirator, coveralls

Job responsibilities)
Operating procedures) See Work Practices Section
Maintenance practices)

C. Dynacast: Stacks of alternating negative and positive (wrapped) plates are joined by casting lead straps along the rows of negative and positive plate lugs to make an element which becomes a cell of the complete battery.

Equipment used: Dynacast machine

Material processed: lead, positive and negative plates

Controls: a. downdraft stack jogging station,
b. ventilated Dynacast machine enclosure,
c. lead pot enclosure,
d. cell setting slot ventilation

Crew size: 1

Safety equipment: respirator, coveralls

Job responsibilities)
Operating procedures) See Work Practices Section
Maintenance practices)

II. ENGINEERING CONTROLS

Engineering and work practice controls evaluations have been completed for the above operations. A description of the evaluations is described below. The results of the testing is described in Section 4, Air Monitoring Data.

PASTE MIXING: Segmented sampling was performed on the mixer operator on July 18, 1985. Employee exposure was evaluated during each job function for the work shift including; barrel dumping, adding expander, loading tub with paste, relieving pasting line operator, and end of shift cleanup.

Dust measurements at the mixer indicated leakage through mixer doors during the dry cycle. New gasketing material has been installed and leakage has been eliminated.

Work practices in mixer area will be improved. Operator did not keep walking areas wetted down. In addition, tubs were not routinely cleaned. Tubs will be cleaned after each use with long-handled scraping knife and washed down.

Velocity measurements at the barrel dumping hood indicate an average face velocity of 100 feet per minute. The feasibility of increasing fan speed is being studied. If fan speed cannot be increased either fan will be replaced or opening to hood will be decreased to maintain a minimum of 250 fpm through opening.

PLATE PASTING: Area and segmented personal sampling was performed on employee on July 24, 1985. The sampling included the following job functions: positioning tub of paste and loading machine, loading grids, clearing out machine jam-ups, end of shift cleanup.

Area sampling indicated a background lead concentration of 30 ug/M^3. Additional monitoring with a portable dust monitor indicated the sources of exposure to be fork lift traffic in adjacent aisleways and dust escaping from the drying oven. The oven will be enclosed all the way to the floor since it was found that hot air was blowing out of the oven at a rate of 150 fpm. In addition, oven cleanout will be performed each shift and exhaust ventilation balanced to maintain negative pressure on the oven.

Adjacent aisleways will be vacuumed or cleaned with wet scrubber each shift. Need to install plastic curtain barriers around pasting line to lower background levels will be considered if cleanup does not sufficiently lower air lead levels.

After implementation of these controls, employee will be reevaluated and source identification re-examined. Feasibility of installing laminar flow hood will be evaluated.

DYNACAST: Dynacast source identification and segmented sampling will be performed during the week of August 12-16, 1985. Work practices including vacuuming racks, drossing lead pot, wet down of work area, and disposal of plate. Need for a ventilated scrap barrel will be evaluated.

III. TECHNOLOGY TO BE EVALUATED IN MEETING 50 UG/M^3 PEL

Technology for controlling lead exposure and meeting the PEL may be divided into seven categories.

(1) Automation
(2) Process changes
(3) Machine changes
(4) Local exhaust ventilation
(5) Make-up air supply
(6) Work practices
(7) Housekeeping

These controls will be evaluated as follows to comply with the OSHA Lead Standard. (Numbers below refer to the categories listed above.)

Paste Mixing:

(4) Increased ventilation rate for barrel dumping hood and/or minimize hood openings.

(5) SAI flow or clean air island.

(6) Wet down of work area.

(7) Cleaning of tubs after each use.

Plate Pasting:

(4) Complete enclosure of drying oven, balance oven exhaust. Plastic curtain barrier around pasting line.

(5) SAI at work station.

(7) Clean-out of oven each shift, cleaning adjacent aisles each shift.

Dynacast:

(4) Ventilated racks and scrap barrels.

(5) SAI or clean air island.

(6) Wet down of work areas.

(7) Vacuuming racks.

IV. AIR MONITORING DATA

Operation	Date	Time Period	ug/M^3
Paste Mixing Operator	7/18/85	0700-1530	85
Barrel dumping (3 barrels)	" "	0800-0815	575(2000)
Adding expander	" "	0820-0830	750(3700)
At door to mixer	" "	0830	(8000)
Relief pasting line	" "	0900-0945	100
Loading tub	" "	1130-1145	25(75)
Cleaning tub	" "	1150-1200	200(500)
Barrel dumping (4 barrels)	" "	1330-1350	675(2400)
Adding expander	" "	1350-1400	800(4500)
End of shift cleanup	" "	1510-1525	250
Plate Paster	7/24/85	0700-1530	100
Mucking paste	" "	0700-0705	90(150)
Loading grids	" "	0706	(10)
Repair jam-up	" "	0818-0828	300(580)
Mucking paste	" "	0900-0915	70(100)
Area sample adj. to oven	" "	0900-0930	100(250)
Area sample adj. to aisle	" "	0900-1020	30(500)
End of shift cleanup	" "	1505-1530	150(290)

The following data were obtained after work practices were improved in the paste mixing area and after door gaskets had been replaced and face velocity of barrel dumping hood had been increased to 250 fpm.

Paste Mixing Operator	9/5/85	0700-1530	35
Barrel dumping (3 barrels)	" "	0808-0823	90(150)
Adding expander	" "	0828-0835	450(1000)
At door to mixer	" "	0850	(50)
Relief pasting line	" "	0940-1030	90
Loading tub	" "	1105-1115	35(80)
Cleaning tub	" "	1140-1150	50(130)
Barrel dumping (4 barrels)	" "	1315-1323	100(190)
Adding expander	" "	1325-1333	100(250)
End of shift cleanup	" "	1515-1528	125

NOTE: Operator TWA exposure excludes periods when other job duties were performed. Values contained in parentheses were obtained with a portable dust monitor and indicate instantaneous total dust concentrations.

V. IMPLEMENTATION SCHEDULE

```
                         AUG         SEP          OCT          NOV
                      9/16/23/30  6/13/20/27  4/11/18/25  1/8/15/22/29
Paste mixing

 New door gaskets     ->I

 Barrel dumping       --------->I
    ventilation

 Wet down work area/  --->I
   tub cleaning

Reevaluation of      --------------->R
  employee exposure

Plate pasting

 Enclose oven/balance -------->I
   ventilation

 Cleanup of adjacent  -->I
   aisles

Laminar air/SAI      ------->S---->D---------->F----->I

Reevaluation of     --------------------------------------------->R
  employee exposure

Dynacast

 Work practices       -->S------>I

 Ventilation-barrel/  ---->S----->D----------->F--------->I
   laminar flow hood

Reevaluation of      --------------------------------------------->R
  employee exposure
```

I = Implement work practices or install engineering controls
S = Feasibility study
D = Design of controls
F = Fabricate engineering controls
R = Resampling to determine employee exposure after controls have been implemented.

WORK PRACTICES

A. General Hygiene Facilities and Practices:

1. Facilities:

   A. A separate locker and shower room for all employees.

   B. Locker area for storage of work clothes and shoes separate from street wear.

B. Practices:

   A. Showering is required of all employees at the end of their work shift.

   B. Towels, wash cloths, and soap are provided.

   C. Personal hygiene:

      1. Wash hands, forearms, and face before eating or drinking.

      2. Carrying or storing of food, drinks, tobacco products, or cosmetics into the plant is prohibited.

      3. There is no eating or smoking in the plant operations area.

      4. The lunchroom provided is to be used for eating and smoking only.

      5. No personal items are to be carried into the plant operations area.

      6. Respirators and hats are to be left in the designated area at break and lunch times and not taken into the lunchroom.

C. Paste Mixing and Plate Pasting

1. Mixer

   a. Job Responsibilities

      Make sure ventilation is working in hood. Position drum of oxide at drum conveyor at rear. Dump drum of oxide already in hoist. Remove empty drum. Slowly remove lid from full drum with no banging. Position lid on empty drum. Position drum in hoist. Open gate before - close after. Push up drums on conveyor to be ready for next mix. Open door of mixer, clear of oxide, add expander. Make sure bag is closed and folded in a ventilated area. Add solka flock, add initial water. Mix three (3) minutes, add oil and dynel fiber, mix one (1) minute, add acid, set final water on meter, mix for two (2) minutes. Check density. Position empty tub under mixer, dump mix into tub hoe, level. Assist operator to position tub of paste.

b. Protective Equipment Required

(1) Safety hat.

(2) Safety glasses (OSHA approved).

(3) Rubber gloves.

(4) Steel toed rubber knee boots.

(5) Outer work clothes (not worn outside plant).

(6) Respirator.

c. Housekeeping - Work Habits

(1) Ascertain ventilation is working properly.

(2) Keep area wet and clean.

(3) Do not open drums in unventilated area.

(4) Have scrap containers removed as soon as they are full.

(5) Before coming to break or lunch - thoroughly wash off boots, removing excess mud. Remove boots and outer work clothes.

(6) Cleanup large spills as soon as possible using a water hose.

(7) At end of shift, clean work area, dump excess paste in take off table waste container.

d. Hygiene Facilities

(1) Facilities

  (a) Separate locker and shower rooms for all employees.
  (b) Lockers - have area for storage of work clothes, shoes separate from street wear.

(2) Practices

  (a) Showering is required of all employees at end of shift.
  (b) Towels, wash cloths and soap are provided.

e. Personal Hygiene

(1) Wash hands, forearms, face before eating or smoking.

(2) Carrying or storing of food, drinks, tobacco products, or cosmetics into the plant is prohibited.

(3) There is no eating, smoking in the plant operations area.

(4) The lunchroom provided is to be used for eating and smoking only.

(5) No personal items are to be carried into the plant operations area.

(6) Respirators and hats are to be left in the designated area at break and lunch times and not taken into the lunchroom.

2. Paster Operator

NOTE: The same type of information is provided for all other operations where employees are exposed to lead in excess of 50 ug/M^3.

APPENDIX B
CONSULTATIVE SERVICES

I. OSHA ON-SITE CONSULTATION PROJECT DIRECTORY

State	Telephone
Alabama	(205)348-7136
Alaska	(907)276-5013
Arizona	(602)255-5795
Arkansas	(501)375-8442
California	(415)557-2870
Colorado	(303)491-6151
Connecticut	(203)566-4550
Delaware	(303)491-6151
Florida	(904)488-3044
Georgia	(404)894-3806
Guam	9-011 (671)477-9821
Hawaii	(808)548-2511
Idaho	(208)385-3929
Illinois	(800)972-4140/4216 (Toll-free in State) (312)793-3270
Iowa	(515)281-5352
Indiana	(317)232-2688
Kansas	(913)296-4086
Kentucky	(502)564-6895
Louisiana	No Services Available
Maine	(207)289-3331
Maryland	(301)659-4210
Massachusetts	(617)727-3567
Michigan (Health)	(517)373-1410
Michigan (Safety)	(517)322-1809
Minnesota	(612)296-2973
Mississippi	(601)982-6315
Missouri	1-(800)392-0208 (314)751-3403
Montana	(406)449-3402
Navajo Nation	(602)871-6335
Nebraska	(402)471-4712
Nevada	(702)885-5240
New Hampshire	(603)271-3170
New Jersey	(609)984-3407
New Mexico	(505)841-6596
New York	(212)488-7746/7
North Carolina	(919)733-4885
North Dakota	(701)224-2366
Ohio	(800)282-1425 (Toll-free in State) (614)466-7485
Oklahoma	(405)521-2461
Oregon	(503)378-3273
Pennsylvania	(415)357-3019
Puerto Rico	(809)754-2134/2171
Rhode Island	(401)277-2438
South Carolina	(803)758-8921
South Dakota	(605)688-4101
Tennessee	(615)741-2793
Texas	(512)458-7287
Utah	(801)530-6868
Vermont	(802)828-2765
Virginia	(804)786-5875(S) (804)786-5873(H)
Virgin Islands	(809)772-1315
Washington	(206)753-6500
Washington, D.C.	(202)576-6339
West Virginia	(304)348-7890
Wisconsin	(608)266-0417(H) (608)544-8686(S)
Wyoming	(307)777-7786

II. OSHA Area Offices

AK	Alaska	Anchorage	907-271-5152
AL	Alabama	Birmingham	205-822-7100
AR	Arkansas	Little Rock	501-378-6291
AZ	Arizona	Phoenix	602-241-2007
CA	California	Berkeley	415-486-3410
CO	Colorado	Denver	303-837-5285
CT	Connecticut	Hartford	203-244-2294
FL	Florida	Fort Lauderdale	305-527-7292
		Jacksonville	904-791-2895
		Tampa	813-228-2821
GA	Georgia	Tucker	404-221-4767
HI	Hawaii	Honolulu	808-546-3157
IA	Iowa	Des Moines	515-284-4794
ID	Idaho	Boise	208-334-1867
IL	Illinois	Calumet City	312-891-3800
		Niles	312-631-7033
		North Aurora	312-896-8700
		Peoria	309-671-7033
IN	Indiana	Indianapolis	317-269-6644
KS	Kansas	Wichita	316-269-6644
KY	Kentucky	Frankfort	502-227-7024
LA	Louisiana	Baton Rouge	504-389-0474
ME	Maine	Augusta	207-622-8417
MA	Massachusetts	Springfield	315-785-0123
		Waltham	617-647-8681
MD	Maryland	Baltimore	301-962-2840
MI	Michigan	Detroit	313-226-6720
MN	Minnesota	Minneapolis	612-349-5994
MO	Missouri	Kansas City	816-374-2756
		St. Louis	314-263-2749
MS	Mississippi	Jackson	601-960-4606
MT	Montana	Billings	406-657-6649
NC	North Carolina	Raleigh	919-755-4770
ND	North Dakota	Bismarck	701-255-4011, Extension 521
NE	Nebraska	Omaha	402-221-3182
NH	New Hampshire	Concord	603-224-1995
NJ	New Jersey	Belle Mead	201-359-2777
		Camden	609-757-5181
		Dover	201-361-4050
		Hasbrougck Heights	201-288-1700
NM	New Mexico	Albuquerque	505-776-3411
NV	Nevada	Carson City	702-883-1226
NY	New York	Albany	518-472-6085
		Buffalo	716-846-4881
		Flushing	212-445-5005
		New York	212-264-9840
		Syracuse	315-423-5188
		Westbury	516-334-3344

OH	Ohio	Cincinnati	513-684-3784
		Cleveland	216-522-3818
		Columbus	614-469-5582
		Toledo	419-259-7542
OK	Oklahoma	Oklahoma City	405-231-5351
OR	Oregon	Portland	503-221-2251
PA	Pennsylvania	Harrisburgh	412-644-2903
		Philadelphia	215-597-4955
		Pittsburgh	412-644-2903
		Wilkes-Barre	717-826-6538
PR	Puerto Rico	Hato Rey	809-753-4457
RI	Rhode Island	Providence	401-528-4669
SC	South Carolina	Columbia	803-765-5904
TN	Tennessee	Nashville	615-251-5313
TX	Texas	Austin	512-482-5783
		Corpus Christi	512-888-3257
		Houston	713-750-1727
		Irving	214-767-5347
		Lubbock	806-743-7681
UT	Utah	Salt Lake City	801-524-5080
WA	Washington	Bellevue	206-442-7520
WI	Wisconsin	Appleton	414-734-4521
		Milwaukee	414-291-3315
WV	West Virginia	Charleston	304-347-5937

READEX FICHE best copy available

III. NIOSH Office Addresses

National Institute for Occupational Safety and Health (NIOSH)
4676 Columbia Parkway, Cincinnati, OH 45226;
944 Chestnut Ridge Road, Morgantown, WV 26505;
1600 Clifton Road, NE, Atlanta, GA 30333

NIOSH Regional Offices

Region I (CT, ME, MA, NH, RI, VT)
Government Center
(JFK Federal Building)
Room 1401
Boston, MA 02203
Tel: (617)223-3848

Region II (NJ, NY, PR, VI)
26 Federal Plaza, Room 3337
New York, NY 10278
Tel: (212)264-2485/8

Region III (DE, DC MD, PA, VA, WV)
P.O. Box 13716
Philadelphia, PA 19101
Tel: (215)596-6716

Region IV (AL, FL, GA, KY, MS, NC, SC, TN)
101 Marietta Towers
Suite 1007
Atlanta, GA 30323
Tel: (404)221-2396

Region V (IL, IN, MI, MN, OH, WI)
300 South Wacker Drive, 26th Floor
Chicago, IL 60606
Tel: (312)886-3651

Region VI (AR, LA, NM, OK, TX)
1200 Main Tower Building
Room 1835
Dallas, TX 75202
Tel: (214)767-3916

Region VII (IA, KA, MO, NE)
5th Floor West
601 East 12th Street
Kansas City, MO 64106
Tel: (816)374-3491

Region VIII (CO, MT, ND, SD, UT, WY)
FOB, Room 1185
1961 Stout Street
Denver, CO 80294
Tel: (303)837-6163

Region IX (AZ, CA, HI, NV)
Room 303
50 United Nations Plaza
San Francisco, CA 94102
Tel: (415)556-3781

Region X (AK, ID, WA)
Mail Stop 402
2901 Third Avenue
Seattle, WA 98121
Tel: (206)442-0530

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2. ACGIH Ventilation Manual, 18th Edition, 1984

3. Information provided by the joint technical committee composed of union, industry, and government personnel.

4. Engineering drawings provided by D. Jeff Burton, IVE Inc., Salt Lake City, Utah.

5. Industrial Hygiene Aspects of Plant Operations: Volume 3, Engineering Considerations in Equipment Selection, Layout, and Building Design, Chapter Twenty-Two, Lead-Acid Battery Manufacturing by Lawrence F. Bullock.

6. Small Businessman's Guide to the OSHA Lead Standard, International Lead Zinc Research Organization Inc.

APPENDIX C
PRIMER ON INDUSTRIAL VENTILATION
By D. JEFF BURTON

Pressure

Air moves under the influence of differential pressures. A fan is commonly used to create this difference of pressure in a duct system. At sea level the standard static pressure of air is 14.7 psi, or 29.92 inch Hg, or 407 inches of water. If the fan generates one inch of negative static pressure ("1 inch w.g., SP"), as shown in the Figure 1, then the absolute static pressure in the duct will be 406 inches water gage pressure and can be measured with a manometer.

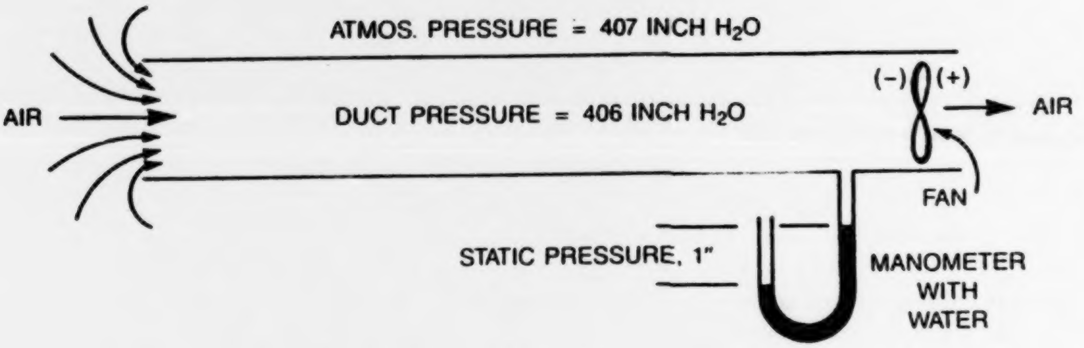

ATMOS. PRESSURE = 407 INCH H2O
AIR
DUCT PRESSURE = 406 INCH H2O
(–)
(+)
AIR
FAN
STATIC PRESSURE, 1"
MANOMETER
WITH
WATER

Figure 1. Pressure Differences Create Air Movement

A manometer can also be used to measure total pressure (TP) and velocity pressure (VP), as shown in the Figure 2. As can be seen, pressures are related as follows:

$$TP = SP + VP \quad (1)$$

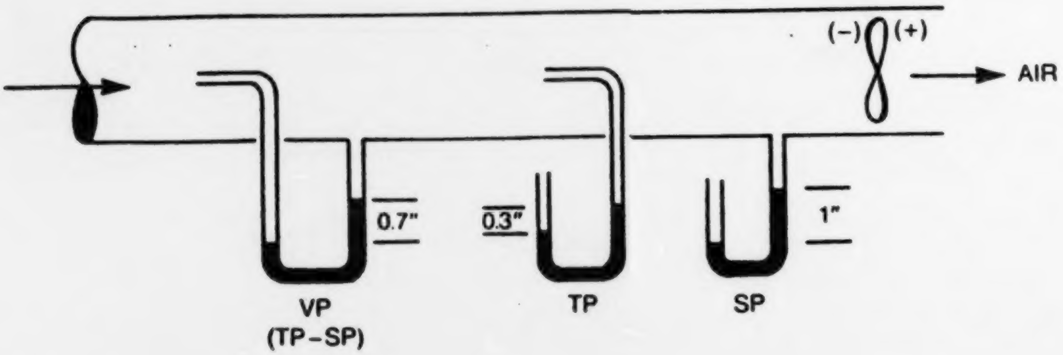
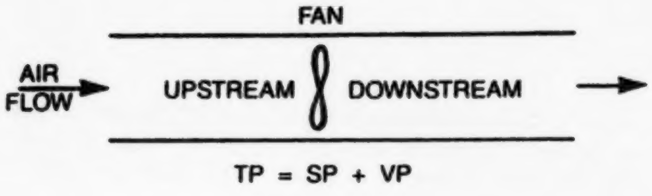

(–)
(+)
AIR
0.7"
0.3"
1"
VP
(TP–SP)
TP
SP

Figure 2. Pressures

Convention calls for labeling pressures as positive or negative quantities. Figure 3 shows the common sign convention


FAN
AIR FLOW
UPSTREAM
DOWNSTREAM
TP = SP + VP

	TP	SP	VP
UPSTREAM	–	–	+
DOWNSTREAM	+	+	+

Figure 3. Pressure and Signs

The velocity pressure (VP) is directly related to velocity in the duct. An approximation of velocity at standard conditions is given by Bernoulli's relationship:

$$V = 4005 \sqrt{VP} \tag{2}$$

where VP = velocity pressure, inches water gage (inch w.g.)
V = velocity, feet per minute (fpm)

Static pressure is the potential energy of the ventilation system. It is converted to kinetic energy (velocity pressure) or t heat (e.g., friction and elbow "losses," air cleaner "pressure drop"). Static pressure increases in quantity as air approaches the fan. See the Figure 4. System design is intended to estimate necessary static pressure needs prior to system construction.

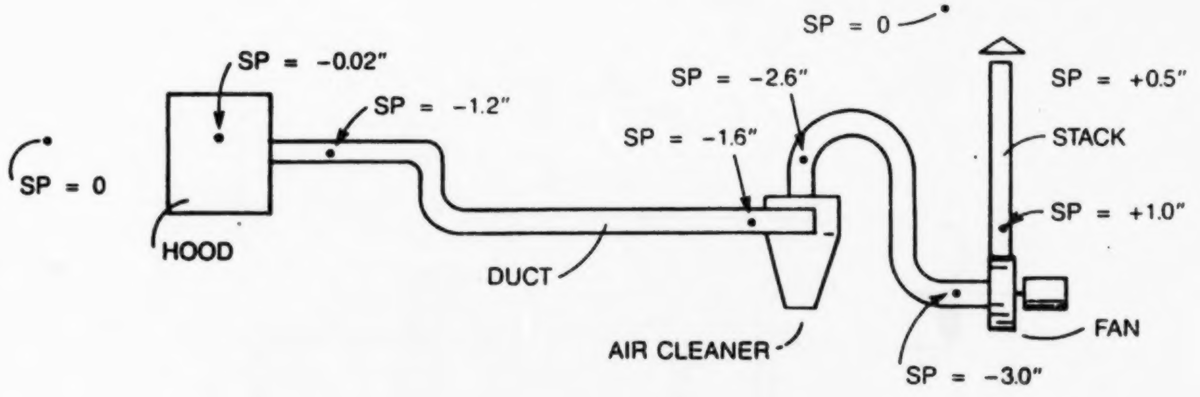

SP = 0
SP = –0.02"
SP = –1.2"
HOOD
DUCT
SP = –1.6"
SP = –2.6"
AIR CLEANER
SP = 0
SP = –3.0"
FAN
SP = +1.0"
STACK
SP = +0.5"

Figure 4. Static Pressures in a System

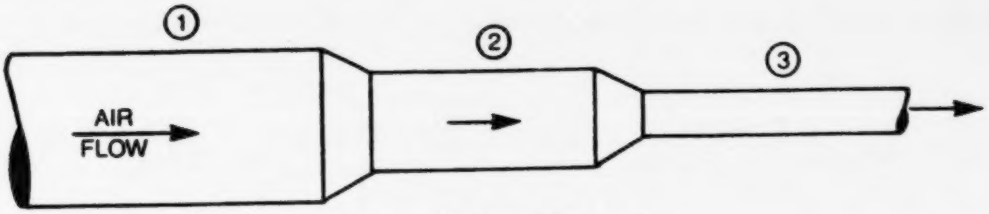
Flow Rates

Volume flow rates are described by the conservation of mass formula:

$$Q = VA \tag{3}$$

where Q = volume flow rate, cubic feet per minute (cfm)
A = cross-sectional area of the duct (door, etc), square feet (sq.ft.)
V = velocity, feet per minute (fpm)

This is shown on the figure below



$$V_1A_1 = V_2A_2 = V_3A_3 = Q$$

Hoods

Hoods capture, contain, or receive contaminants before they have a chance to dilute into workroom air. See Figure 5. The hood is also intended to convert static pressure to velocity pressure. Unfortunately, during conversion heat is also generated due to the vena contracta formed at the entrance to the duct. See Figure 6. This entry loss is called the "hood entry loss, He" and can be estimated from the following formula:

$$He = |SPh| - VP \tag{4}$$

where He = Hood Entry Loss, inches w.g.
VP = Velocity pressure in the duct, inches w.g.
SPh = Absolute value of static pressure in the duct near the hood, inches w.g.

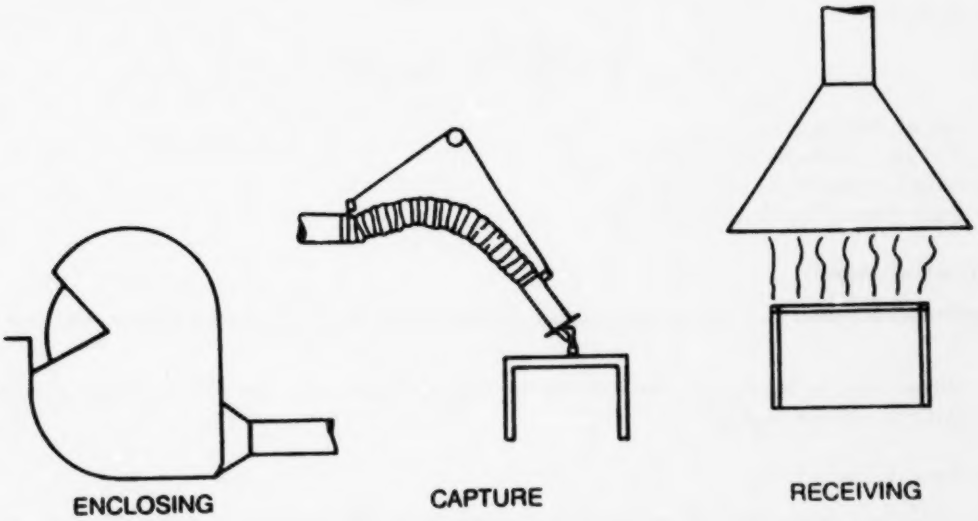


Figure 5. Hood Types

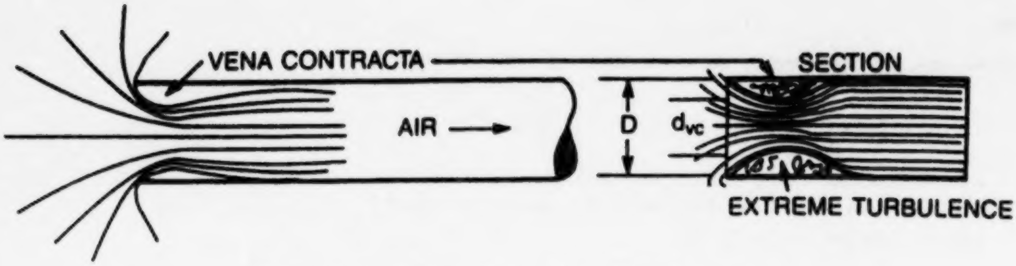


Figure 6. Hood Entry Loss and the Vena Contracta

He and SPh are usually measured 4-6 duct diameters downstream from the hood as shown in Figure 7.

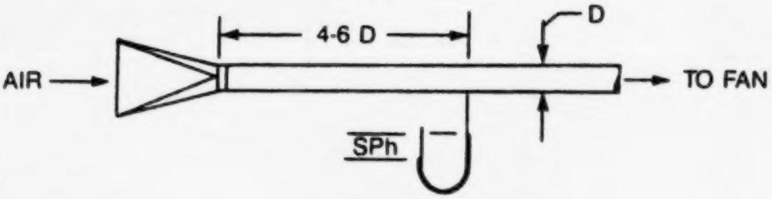


Figure 7. SPh Measurement

A measure of the effectiveness of the hood in converting static pressure to velocity pressure is given by the "Coefficient of Entry, Ce" and is calculated as follows:

$$Ce = \sqrt{\frac{VP}{SPh}} \tag{5}$$

where Ce = Coefficient of Entry, unitless
VP = Velocity pressure in duct, inches w.g.
SPh = Absolute value of the Static Pressure in the duct near the hood, inches w.g.

The Coefficient of Entry should be estimated for all hoods because of its usefulness in estimating flow rates at any future time. Note that in Equation (6) only the static pressure need be measured to estimate flow rate. (Assuming the hood has not changed physically.):

$$Q = 4005 \cdot A \cdot C_e \cdot \sqrt{SPh} \tag{6}$$

where Q = volume flow rate, cfm
A = duct cross-sectional area, sq. ft.
Ce = hood Coefficient of Entry, unitless
SPh = Static pressure at hood, inches w.g.

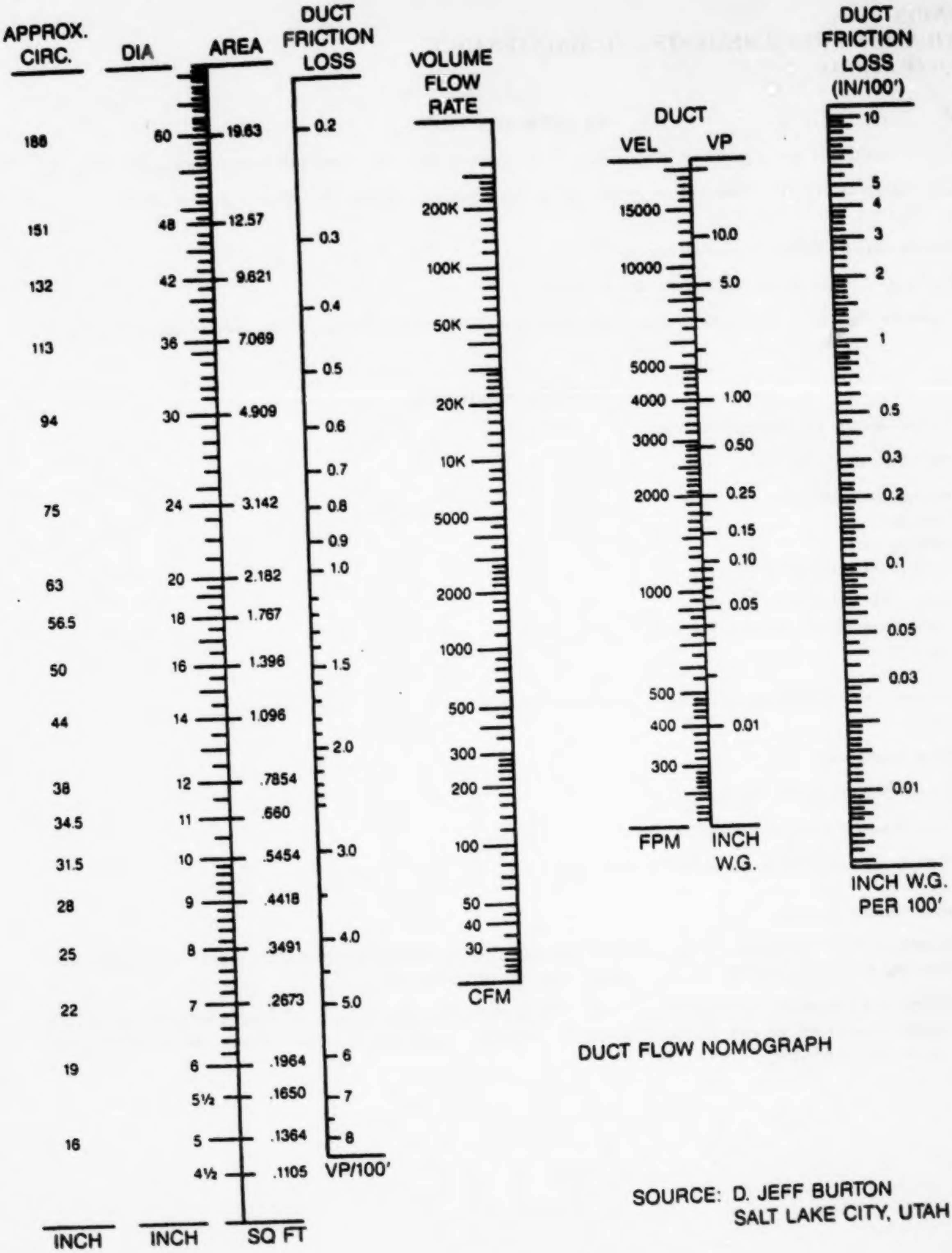
Slot and Transport Velocity

Compound hoods (dual entry — a slot entry to a plenum plus a duct entry) are usually built with a slot velocity of 1,500-2,000 fpm.

Transport velocity must be maintained in the duct to avoid settling of particulate. Dry lead oxide dusts commonly require 4,500-5,000 fpm to assure non-settling.

Estimating Flows, Friction Losses

The nomograph shown on the next page can be used to estimate flows and friction losses in ducts. Line up any two known points on a straight edge. All other parameters lie along the straight edge.



DUCT FLOW NOMOGRAPH

SOURCE: D. JEFF BURTON
SALT LAKE CITY, UTAH

APPENDIX D
VENTILATION—MEASUREMENTS AND MAINTENANCE

By D. JEFF BURTON

1.0 INTRODUCTION

Testing and evaluation are required on every industrial ventilation system. Evaluation objectives include the following:

- Determination of the effectiveness of the ventilation system (emissions capture, particulate transport, employee protection, efficiency, air cleaning.)
- Establishment of baseline or start-up conditions.
- Monitoring of conditions throughout the life of system.

This appendix provides an explanation of the basic measurements normally performed and some measurement tips.

2.0 TESTING EQUIPMENT

Basic testing devices are summarized below.

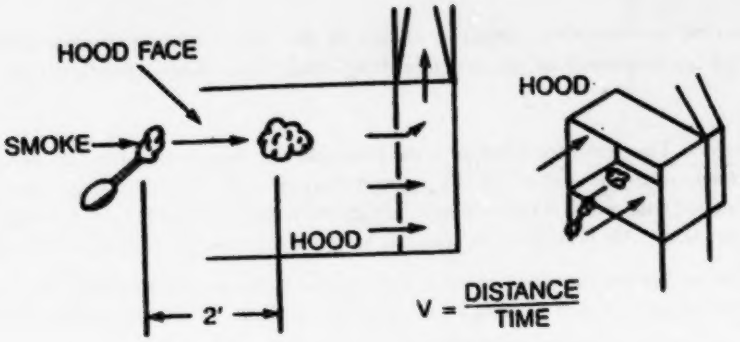
- Smoke tubes, smoke bombs.
- Velometers, anemometers
  - Rotating vane
  - Swinging vane
  - Thermal/hot wire anemometer
- Pressure sensing devices
  - U-tube manometers, inclined manometers, hook gauges
  - Pitot tube
  - Swinging vane
  - Thermal (The thermal and the swinging vane instruments measure static pressure indirectly.)
  - Bellows
- Voltage and amperage meters
- Noise and vibration monitoring equipment
- Tapes and distance measuring devices

Some of these are described in the following paragraphs.

Smoke Tubes; Smoke Bombs

Smoke is useful because it is visible. Nothing convinces management or employees more quickly than to show smoke drifting away from the hood, escaping the hood, or traveling into the breathing zone.

Smoke can be used to provide a rough estimate of face velocity as shown below. Squeeze off a quick burst of smoke. Time the smoke plume's travel over two feet. Calculate the velocity in feet per minute. For example, if it takes two seconds to travel two feet, the velocity is 60 fpm.



$$V = \frac{\text{DISTANCE}}{\text{TIME}}$$

FOR EXAMPLE

$t = 2$ SECONDS

$d = 2$ FT

$$V = \frac{2\ \text{FT}}{2\ \text{SEC}} \times \frac{60\ \text{SEC}}{1\ \text{MIN}} = 60\ \text{fpm}$$

Limitations: Smoke can be used for low velocities and estimation purposes only. Smoke candles are incendiary and thus cannot be used in flammable atmospheres. Preferably they should not be hand held.

Velometers, Anemometers

. Rotating Vane Anemometer: This instrument is accurate and can be used to determine air flow through large supply and exhaust openings. The standard instrument consists of a propeller or revolving vane connected through a gear train to a set of recording dials that read the linear feet of air passing in a measured length of time. It is made in various sizes, 3", 4" and 6" being most common. It gives average flow for time of test (usually one minute). Each instrument requires frequent calibration and the use of a calibration card or curve to determine actual velocity. The standard instrument has a useful range of 200-3000 fpm; especially-built models will read lower velocities.

Limitations: The rotating vane anemometer is unsuited for measurement in ducts as it has too large a finite area. The conventional meter is not direct reading and must be timed. It is fragile and cannot be used in dusty and corrosive atmospheres.

Swinging Vane Anemometer (Velometer): This instrument is extensively used in field measurements because of its portability, wide-scale range and instantaneous reading features. The instrument has wide application and by a variety of fittings, can be used to check static pressures and a wide range of linear velocities. The minimum velocity is 50 fpm. The instrument is fairly rugged and accuracy is suitable for most field checks.

The meter should be used always in an upright position (handle on top) and, when using fittings, it must be held out of the air stream so that the air flows directly into the opening. The length and inside diameter of the connecting tubing affect the calibration of the meter. Use only connecting tubing of the same length and inside diameter as that originally supplied with the meter. Changes in tubing do affect the calibration of the meter.

Limitations: Used in place of a Pitot tube for velocity measurements, it necessitates a much larger hole in the duct, oftentimes difficult and impractical to provide. When the velocities are high there may be appreciable errors at the high end of the scale and the instrument may tend to read low on the blowing side of the fan and high on the suction side.

The presence of dust, moisture or corrosive material in the atmosphere presents a problem since the air passes through the instrument. In those instruments calibrated for use with a filter (the filter must always be used), the filter itself is a source of error since as the filter becomes plugged its resistance increases and thus alters the amount of air passed to the swinging vane. The instrument requires periodic calibration and adjustment.

Heated Wire Anemometer: The hot-wire anemometer depends on the variation of the resistance of a wire with temperature. When a stream of air passes over a heated wire, heat removal from the wire depends on the velocity of the air stream and thus the temperature of the wire and its resistance, vary with the air velocity.

Limitations: The probe on the portable instrument is subject to fouling by dust and corrosion. It should be calibrated at regular intervals. Instruments are not recommended for use in combustible atmospheres unless specifically approved for this service.

Heated Thermocouple Anemometers: This instrument employs the principle that heat removal by an air stream passing a heated object is related to the velocity of the air stream. A hot junction thermocouple is used to sense the temperature of a heated probe in the air stream; a second cold junction thermocouple senses the temperature of the air. A voltage is generated between the heated and unheated junctions. Air flow tends to cool the heated thermocouple, decreasing its voltage output.

The instrument is most suited for measuring low velocities, room air currents and hood opening velocities. Certain instruments with small probes can be used for measurement of duct velocities lower than the capability of velocity pressure sensing devices.

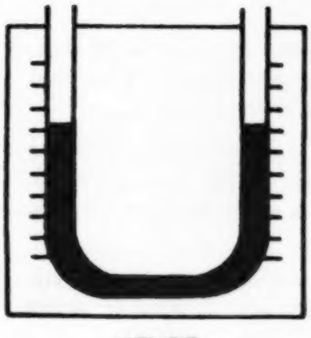
Limitations: Portable battery-powered meters tend to fade in voltage during use necessitating frequent adjustment. Probes tend to be fragile and must be handled carefully. There is a need for frequent calibration. The delicate wires in the probe are easily damaged. The instrument should not be used in corrosive or dusty atmospheres.

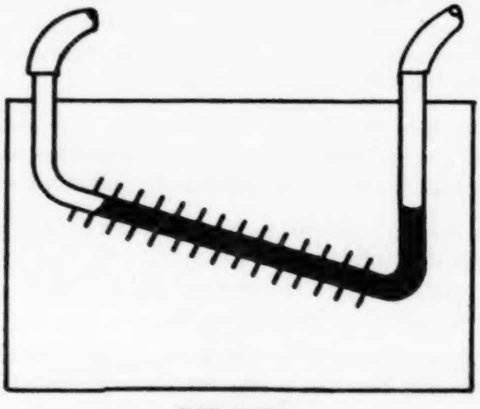
Pressure Sensing Devices

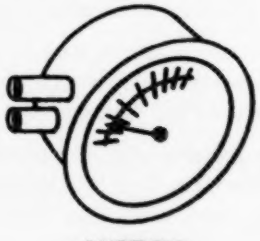
U-Tube Manometer: The vertical U-tube is the simplest type of pressure gauge. Usually calibrated in inches of water, it is used with various fluid media—such as alcohol, mercury, oil, water, kerosene and special manometer fluids. The U-tube may be used for either portable or stationary applications. Available commercial units offer a wide latitude in range, number of columns and styles. Tubes are usually of all-plastic construction to minimize breakage. One leg may be replaced by a reservoir or well (well-type manometer) with the advantage of easier manometer reading.

Inclined Manometer: Increased sensitivity and scale magnification is realized by tilting one leg of the U-tube to form an inclined manometer or draft gauge. The inclined manometer, usually with 10 to 1 slope, gives increased accuracy and permits lower readings. In commercial versions, only one tube of the small bore is used and the other leg is replaced by a reservoir. The accuracy of the gauge is dependent on the slope of the tubes. Consequently the base of the gauge must be leveled carefully and the mounting must be firm enough to permit accurate leveling. The better draft gauges are equipped with a built-in level, leveling adjustment and, in addition, a means of adjusting the scale to zero. Some models include overpressure safety traps to prevent loss of fluid in event of pressure surges beyond the manometer range.

Aneroid Type Gauges: This type of gauge is used as a field instrument in ventilation studies for measuring static, velocity or total pressure with a Pitot tube or for single tube static pressure measurements. There are a number of manufacturers offering gauges suitable for the measurement of the low pressures encountered in ventilation studies. Principal advantages of this gauge may be listed as follows: easy to read, greater response than manometer types, very portable—of small physical size and weight, absence of fluid means less maintenance and mounting and use in any position is possible with loss of accuracy. Principal disadvantages are that, being a mechanical-type device, the gauge is subject to mechanical failure, requires periodic calibration checks and occasional recalibration.


U-TUBE MANOMETER


INCLINED MANOMETER


ANEROID GAUGE

3.0 GENERAL APPROACH TO MEASUREMENTS

3.1 Physical Measurements

Typical physical measurements include the following:

- Duct diameters, or duct circumference. These are measured for the purpose of calculating duct area. Inside duct diameter is the most important measurement, but an outside measurement is usually sufficient on sheet metal ducts. Duct measurements are often difficult. Measuring tapes seldom lay flat against the duct, ducts are often out of round and they frequently vary from the nominal size by a small percent. So, for example, if your figures indicate the diameter to be 20.1 inches, there is a good probability that the duct is a 20" duct.
- Duct length. Lengths can be estimated from plans, drawings, and specifications. Measurements can be made with tapes or optical devices. If the duct is constructed of 2½- or 4-foot sections, count the sections. Include elbows and tees in the length.
- Radius of curvature. Mostly eyeballing with measuring tape. The most common way of expressing radius of curvature is to divide the center-line radius by the duct width or diameter.
- Sheet metal gauge. The "Mfrs Std. Gauges" for steel sheet metal is based on metal with a density of 490 lbs/cu ft. Galvanized metal is slightly thicker than non-galvanized. Industrial ventilation systems are often constructed of sheet metal, with typical construction in the 12-20 gauge range.

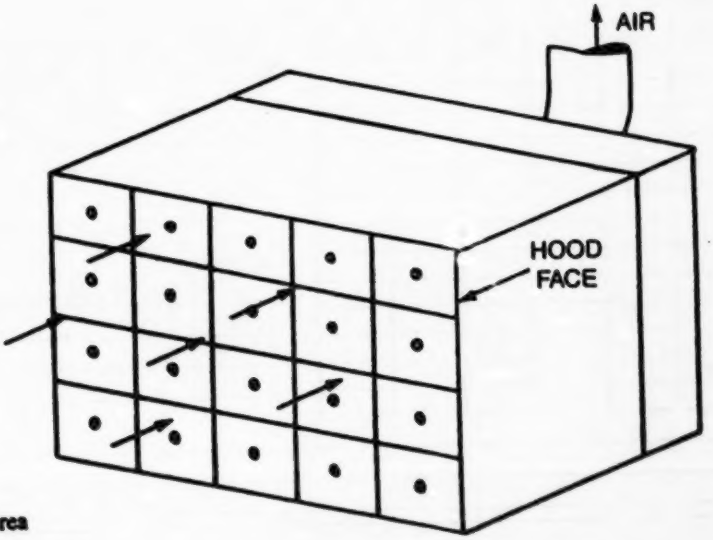
Gauge	Approx. Thickness (inches, galvanized)	Gauge	Approx. Thickness (inches, galvanized)
3	0.24	16	0.064
6	0.20	18	0.051
9	0.15	20	0.040
12	0.11	22	0.034
14	0.078	24	0.028

Gauge can be determined from plans and specifications, or can be estimated using a micrometer.

3.2 Capture and Hood Face Velocities

Velocities outside of the hood, or at the hood face can be estimated with velometers, or smoke generators.

The Figure below shows the method of estimating the average face velocity in a hood face. Velometers and anemometers are well suited to these measurements, however some have velocity correction requirements for non-standard conditions. Check use instructions.



Hood face velocity measurement

- mark off imaginary areas
- measure velocity at center of each area
- average all measured velocities

Figures on the following 6 pages show typical recording sheets and measurement techniques on battery plant equipment.

Typical Recording Form:

Plant ______________________ *Dept.* ______________ *Date* ________

Operation exhausted ______________________________ *By* ________

Line sketch showing points of measurement

Date system installed ______________

Hood and transport velocity

Point	Duct		VP in. H_2O	SP in. H_2O	FPM (Fig. 6-16)	CFM Q = VA	Remarks
	D	Area (Fig. 6-18)					

Pitot traverse

Pitot readings—See Fig. 6-16 & Tables 9-1, 9-2, 9-3

Points	VP	Vel.	VP	Vel.	VP	Vel.
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Total Vel.						
Average Vel.						
CFM						

Fan

Type ______________

Size ______________

Point	Dia.	SP	VP	TP	CFM
Inlet					
Outlet					

Fan SP ____________ *(See Section 6)*

Motor

Name ______________ *Size* ________

HP _____ *E* _____ *I* _____ *W* _____

Collector

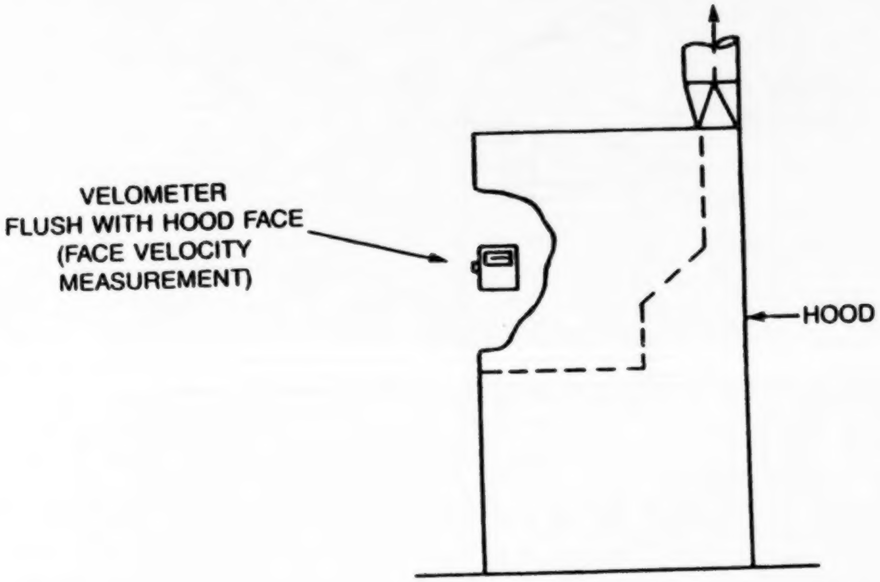
Type & size ______________________

Point	Dia.	SP	Δ SP
Inlet			
Outlet			

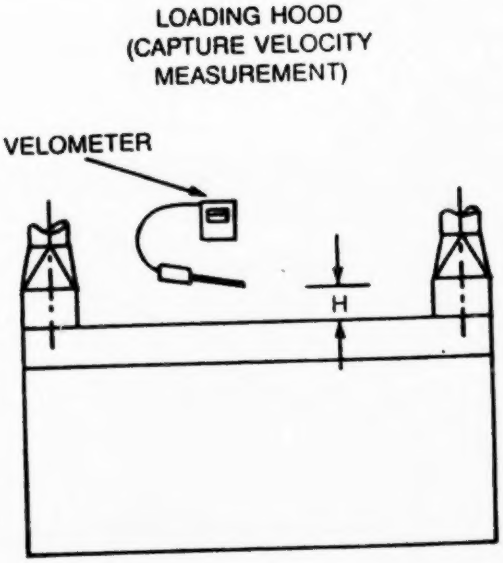
Notes ______________________________________

SOURCE: ACGIH VENT MANUAL, 18TH EDITION

HAND STATION


VELOMETER
FLUSH WITH HOOD FACE
(FACE VELOCITY
MEASUREMENT)
HOOD

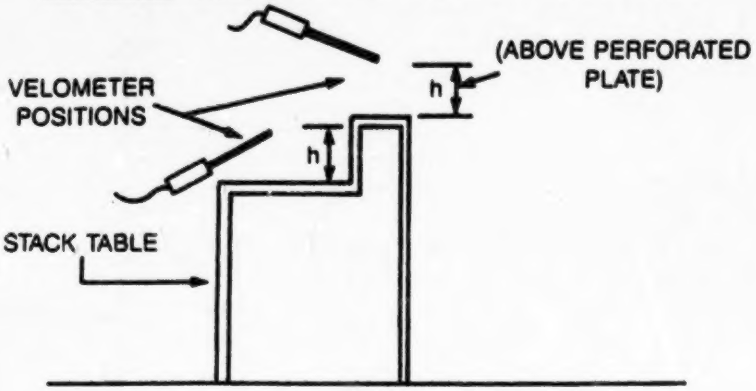
REED STACKER


LOADING HOOD
(CAPTURE VELOCITY
MEASUREMENT)
VELOMETER
H

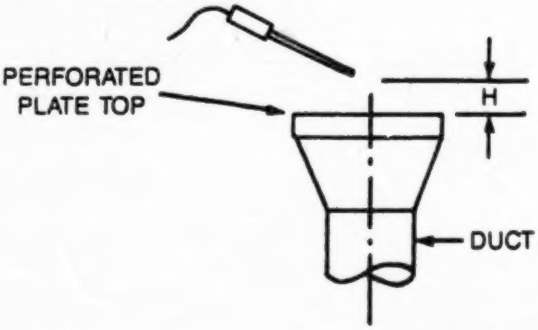
NOTE: H VARIES W/OPERATION

ELEMENT ASSEMBLY

PLATE STACK TABLE (ALSO STACKED GROUP STORAGE)


VELOMETER POSITIONS
h
h
(ABOVE PERFORATED PLATE)
STACK TABLE

TAMP STATION


PERFORATED PLATE TOP
H
DUCT

TIEGEL BURNING MACHINE (IN THE ELEMENT LOADING AND UNLOADING POSITION)

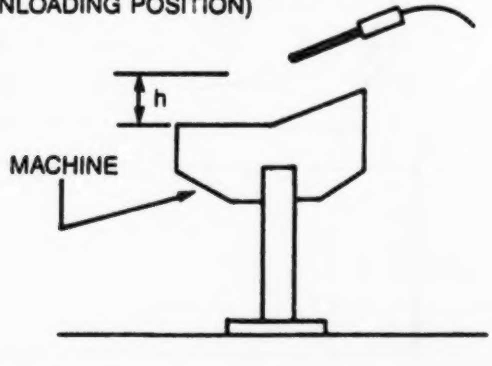
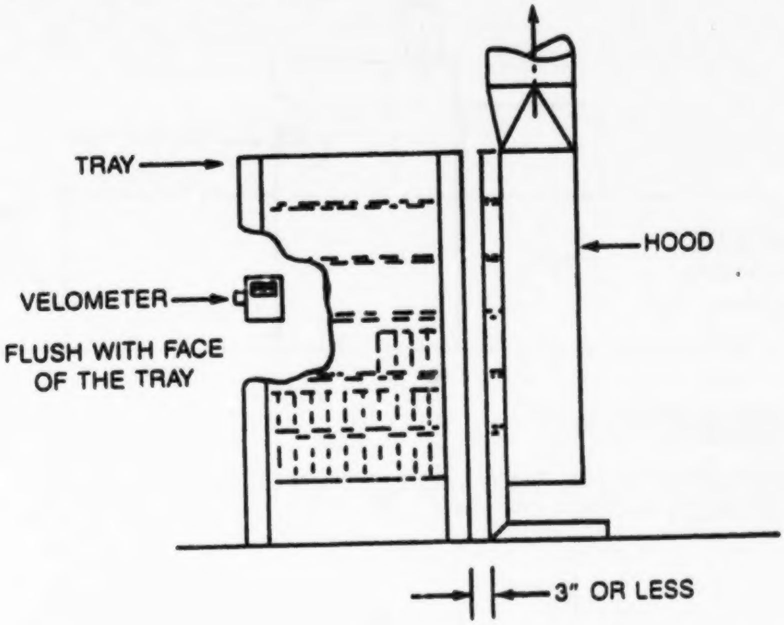


PLATE TRAY—BACK DRAFT HOOD

READ THE VELOCITY FLUSH WITH THE FACE OF THE TRAY WHEN EMPTY OR ONLY PARTLY FILLED.


TRAY
HOOD
VELOMETER
FLUSH WITH FACE OF THE TRAY
3" OR LESS

ENVELOPING WORK TABLES (TYPICAL OF LOADING AND UNLOADING)

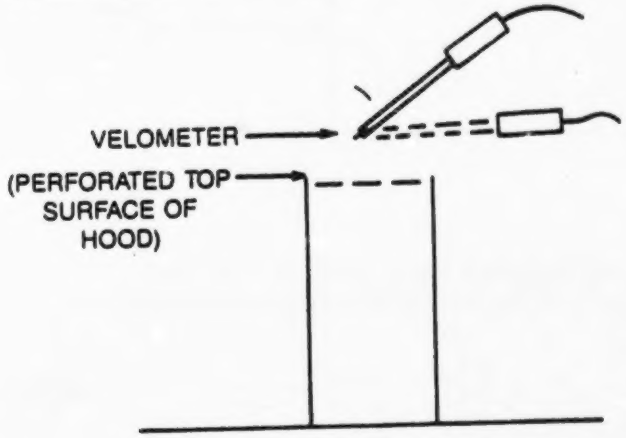
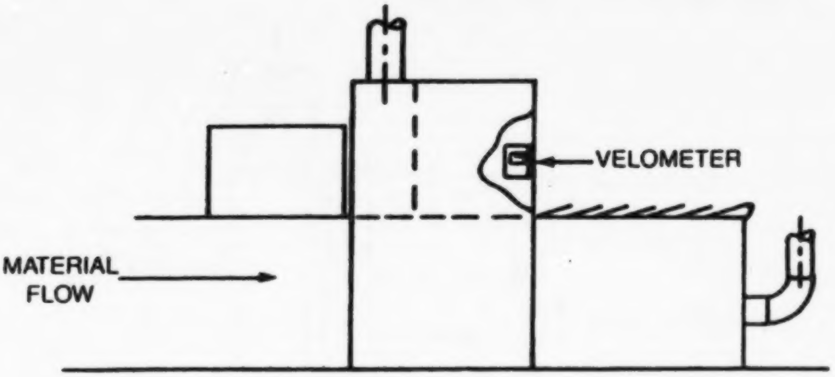

VELOMETER
(PERFORATED TOP SURFACE OF HOOD)

PLATE PARTING STAND (CONTINUED)


VELOMETER
MATERIAL FLOW

BEARDSLEY AND PIPER MIXER

A) DURING PART OF CYCLE WHEN DOOR IS OPEN READ FACE VELOCITY IN DOOR OPENING.

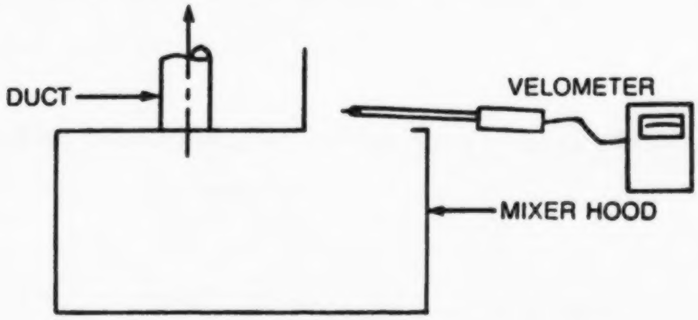
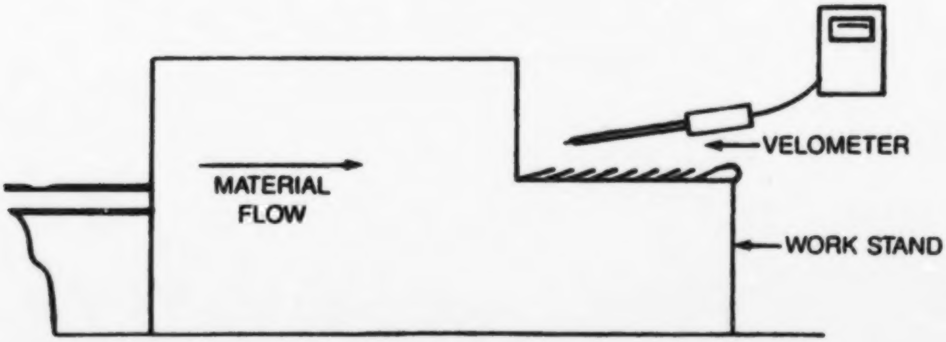
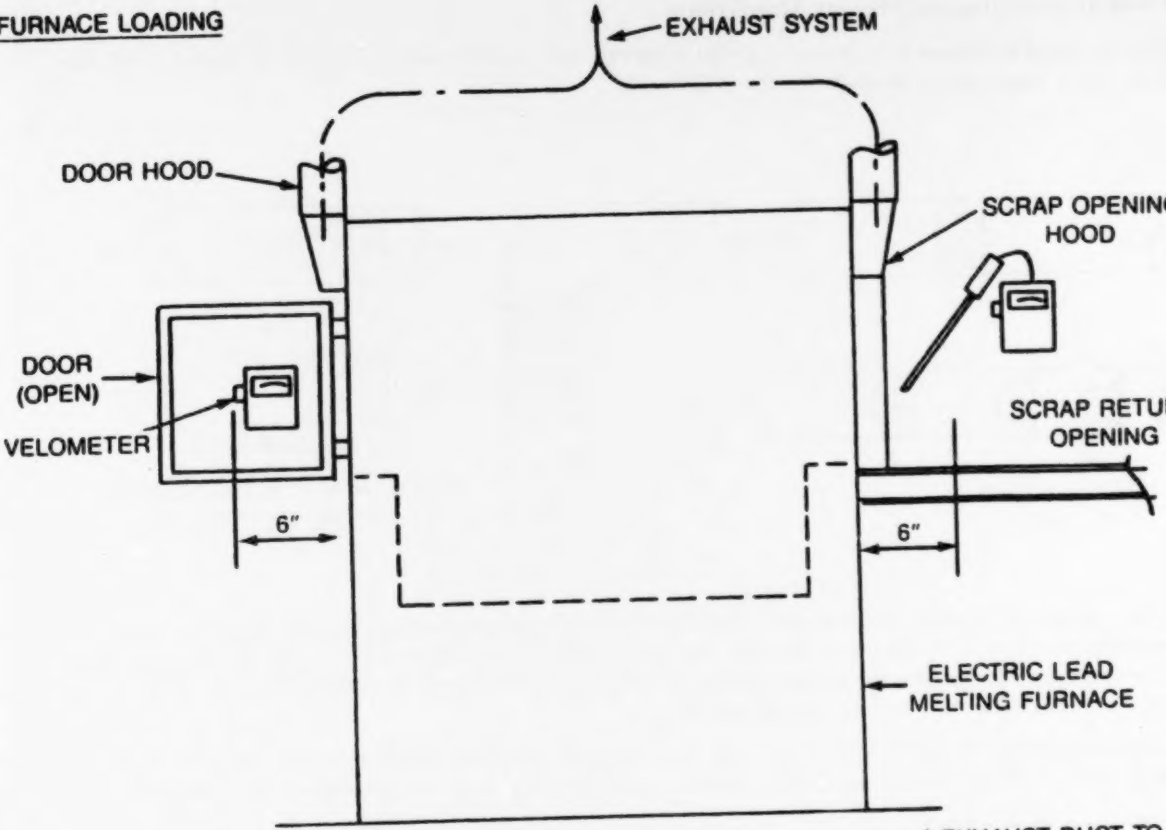

DUCT
VELOMETER
MIXER HOOD

PLATE PARTING STAND

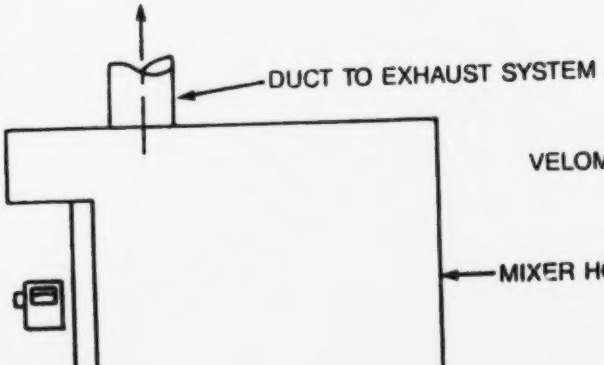
A) PERPENDICULAR UNIT (WORKER FACES LINE) IS READ AS ILLUSTRATED DIRECTLY OVER THE PERFORATED WORK SURFACE.

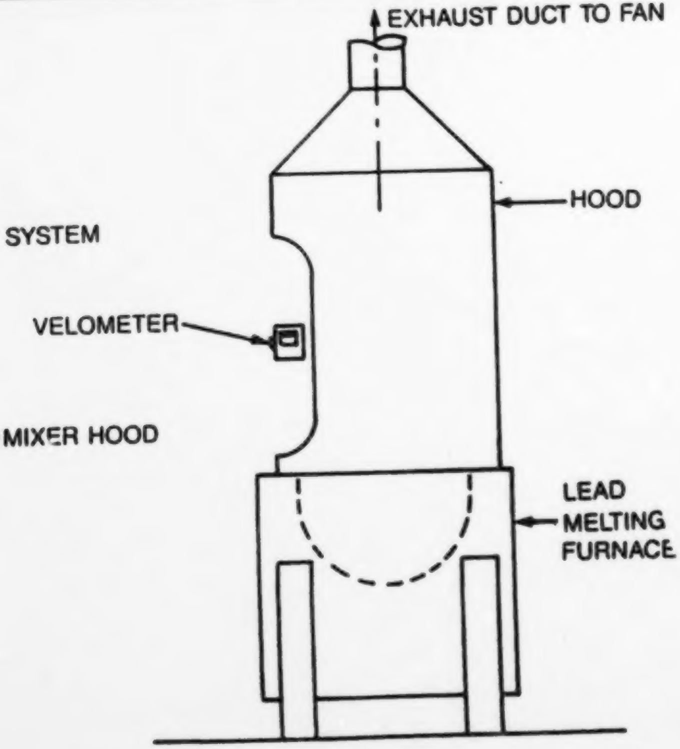

VELOMETER
MATERIAL FLOW
WORK STAND

FURNACE LOADING


EXHAUST SYSTEM
DOOR HOOD
SCRAP OPENING HOOD
DOOR (OPEN)
VELOMETER
SCRAP RETURN OPENING
6"
6"
ELECTRIC LEAD MELTING FURNACE

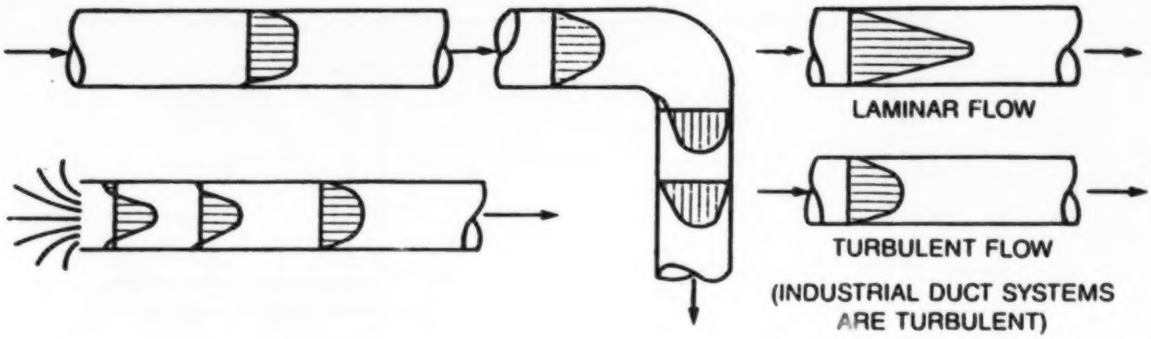
SIMPSON MIXER


DUCT TO EXHAUST SYSTEM
MIXER HOOD


EXHAUST DUCT TO FAN
HOOD
VELOMETER
LEAD MELTING FURNACE

3.3 Duct Velocity Measurements; Pressure Measurement

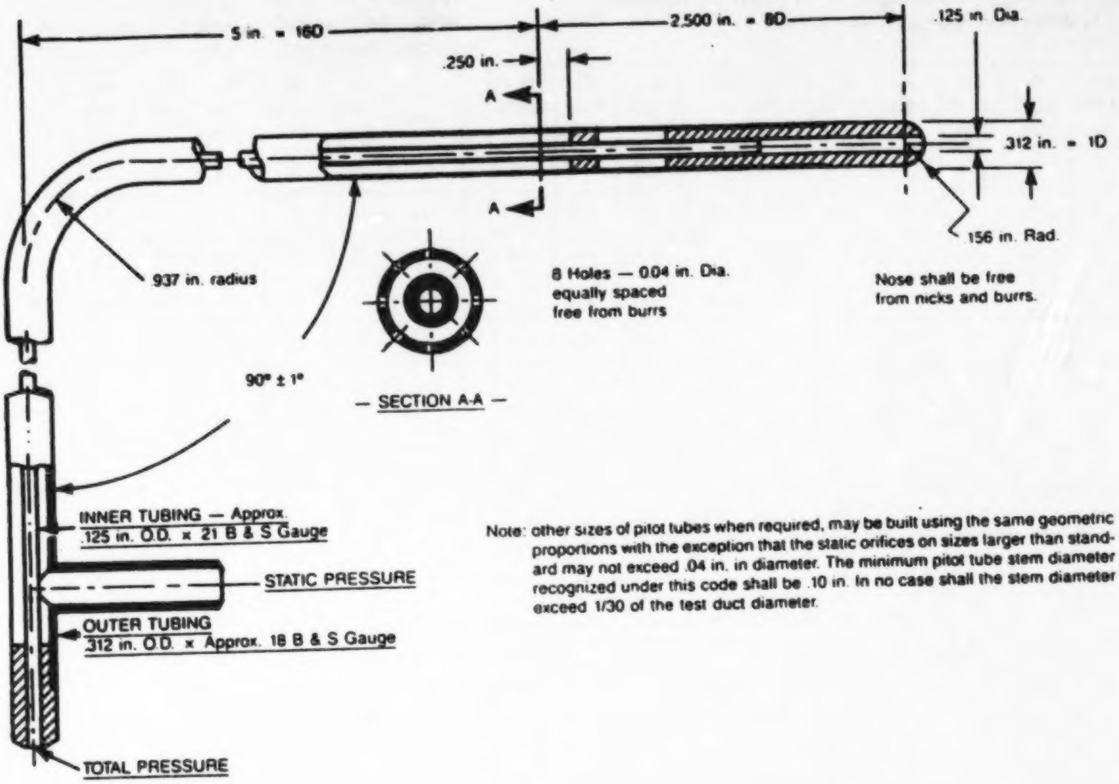
Air flow in industrial ventilation ducts is almost always turbulent, with a small boundary layer at the surface of the duct. The following figure shows typical velocity profiles in ductwork.



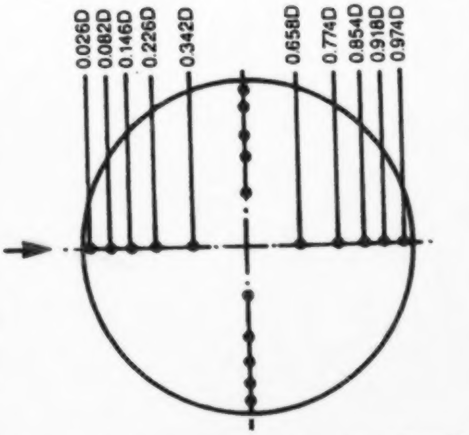
Since velocity varies with distance from the edge of the duct, a single measurement is not usually sufficient. However, if the measurement is taken in a straight length of round duct, 4-6 diameters downstream and 2-3 diameters upstream from obstructions or directional changes, then the average velocity can be estimated at 9/10ths of the centerline velocity. (The average velocity pressure is about 81% of centerline velocity pressure.)

A more accurate method is the pitot traverse. In a pitot traverse, six or ten VP measurements are made on each of two traverses across the duct, 90 degrees opposed. Measurements are made in the center of concentric circles of equal area.

The next two pages show a standard pitot tube and measurement points.

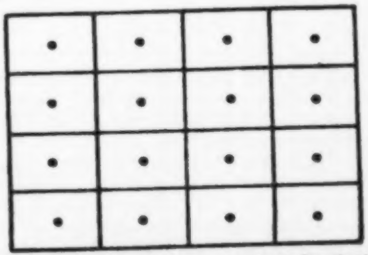

5 in. = 16D
2.500 in. = 8D
.125 in. Dia.
.250 in.
A
A
.312 in. = 1D
.156 in. Rad.
.937 in. radius
8 Holes — 0.04 in. Dia. equally spaced free from burrs
Nose shall be free from nicks and burrs.
90° ± 1°
— SECTION A-A —
INNER TUBING — Approx. .125 in. O.D. × 21 B & S Gauge
STATIC PRESSURE
OUTER TUBING .312 in. O.D. × Approx. 18 B & S Gauge
TOTAL PRESSURE

Note: other sizes of pitot tubes when required, may be built using the same geometric proportions with the exception that the static orifices on sizes larger than standard may not exceed .04 in. in diameter. The minimum pitot tube stem diameter recognized under this code shall be .10 in. In no case shall the stem diameter exceed 1/30 of the test duct diameter.


0.026D
0.082D
0.146D
0.226D
0.342D
0.658D
0.774D
0.854D
0.918D
0.974D

Pitot traverse points in a circular duct. 10 or 20 locations* in centers of equal annular area.

*6 or 12 locations for small ducts. 20 or 40 locations for very large ducts.



Pitot traverse points in a rectangular duct. Centers of 16 to 64 equal areas. Locations not more than 6" apart.

SOURCE: ACGIH VENT MANUAL, 18TH EDITION

DISTANCE FROM WALL OF ROUND PIPE TO POINT OF READING (NEAREST ⅛ INCH) FOR 10-POINT TRAVERSE.

DUCT DIA	R_1 0.026 DIA	R_2 0.082 DIA	R_3 0.146 DIA	R_4 0.226 DIA	R_5 0.342 DIA	R_6 0.658 DIA	R_7 0.774 DIA	R_8 0.854 DIA	R_9 0.918 DIA	R_{10} 0.974 DIA
4	⅛	⅜	⅝	⅞	1⅜	2⅝	3⅛	3⅜	3⅝	3⅞
4½	⅛	⅜	⅝	1	1½	3	3½	3⅞	4⅛	4⅜
5	⅛	⅜	¾	1⅛	1¾	3¼	3⅞	4¼	4⅝	4⅞
5½	⅛	½	¾	1¼	1⅞	3⅝	4¼	4¾	5	5⅜
6	⅛	½	⅞	1⅜	2	4	4⅝	5⅛	5½	5⅞
7	⅛	⅝	1	1⅝	2⅜	4⅝	5⅜	6	6⅜	6⅞
8	¼	⅝	1⅛	1¾	2¾	5¼	6¼	6⅞	7⅜	7¾
9	¼	¾	1¼	2	3⅛	5⅞	7	7¾	8¼	8¾
10	¼	⅞	1½	2¼	3⅜	6⅝	7¾	8½	9⅛	9¾
11	¼	⅞	1⅝	2½	3¾	7¼	8½	9⅜	10⅛	10¾
12	⅜	1	1¾	2¾	4⅛	7⅞	9¼	10¼	11	11⅝
13	⅜	1	1⅞	2⅞	4½	8½	10⅛	11⅛	12	12⅝
14	⅜	1⅛	2	3⅛	4¾	9¼	10⅞	12	12⅞	13⅝
15	⅜	1¼	2¼	3⅜	5⅛	9⅞	11⅝	12¾	13¾	14⅝
16	⅜	1¼	2⅜	3⅝	5½	10½	12⅜	13⅝	14¾	15⅝
17	½	1⅜	2½	3⅞	5¾	11¼	13⅛	14½	15⅝	16½
18	½	1½	2⅝	4⅛	6⅛	11⅞	13⅞	15⅜	16½	17½
19	½	1½	2¾	4¼	6½	12½	14¾	16¼	17½	18½
20	½	1⅝	2⅞	4½	6⅞	13⅛	15½	17⅛	18⅜	19½
22	⅝	1¾	3¼	5	7½	14½	17	18¾	20¼	21⅜
24	⅝	2	3½	5½	8¼	15¾	18½	20½	22	23⅜
26	⅝	2⅛	3¾	5⅞	8⅞	17⅛	20⅛	22¼	23⅞	25⅜
28	¾	2¼	4⅛	6⅜	9⅝	18⅜	21⅝	23⅞	25¾	27¼
30	¾	2½	4⅜	6¾	10¼	19¾	23¼	25⅝	27½	29¼
32	⅞	2⅝	4⅝	7¼	11	21	24¾	27⅜	29⅜	31⅛
34	⅞	2¾	5	7¾	11⅝	22⅜	26¼	29	31¼	33⅛
36	1	3	5¼	8⅛	12⅜	23⅝	27⅞	30¾	33	35
38	1	3⅛	5½	8⅝	13	25	29⅜	32½	34⅞	37
40	1	3¼	5⅞	9	13⅝	26⅜	31	34⅛	36¾	39
42	1⅛	3⅜	6⅛	9½	14⅜	27⅝	32½	35⅞	38⅝	40⅞
44	1⅛	3⅝	6⅜	10	15	29	34	37⅝	40⅜	42⅞
46	1¼	3¾	6¾	10⅜	15¾	30¼	35⅝	39¼	42¼	44¾
48	1¼	4	7	10⅞	16⅜	31⅝	37⅛	41	44	46¾

DISTANCE FROM WALL OF ROUND PIPE TO POINT OF READING (NEAREST ⅛ INCH) FOR 6-POINT TRAVERSE.

DUCT DIA	R_1 .043 DIA	R_2 .146 DIA	R_3 .296 DIA	R_4 .704 DIA	R_5 .854 DIA	R_6 .957 DIA
3	⅛	½	⅞	2⅛	2½	2⅞
3½	⅛	½	1	2½	3	3⅜
4	⅛	⅝	1⅛	2⅞	3⅜	3⅞
4½	¼	⅝	1⅜	3⅛	3⅞	4¼
5	¼	¾	1½	3½	4¼	4¾
5½	¼	¾	1⅝	3⅞	4¾	5¼
6	¼	⅞	1¾	4¼	5⅛	5¾

Velocity in ducts is given by the following relationships:

$$V = 4005\sqrt{VP} \qquad \text{(STP)}$$

OR

$$V = 1096 \; \frac{VP}{0.075d} \qquad \text{(NON-STANDARD CONDITIONS)}$$

where V = VELOCITY, fpm
VP = VELOCITY PRESSURE, INCHES w.g.
d = DENSITY CORRECTION FACTOR

d can be obtained from the following table:

AIR DENSITY CORRECTION FACTOR, d

Altitude, ft.		-1000	Sea Level	1000	2000	3000	4000	5000	6000	7000	8000	9000	10,000
Barometer	"Hg	31.02	29.92	28.86	27.82	26.82	25.84	24.90	23.98	23.09	22.22	21.39	20.58
	"Wg	422.2	407.5	392.8	378.6	365.0	351.7	338.9	326.4	314.3	302.1	291.1	280.1
Air Temp F	-40	1.31	1.26	1.22	1.17	1.13	1.09	1.05	1.01	0.97	0.93	0.90	0.87
	0	1.19	1.15	1.11	1.07	1.03	0.99	0.95	0.91	0.89	0.85	0.82	0.79
	40	1.10	1.06	1.02	0.99	0.95	0.92	0.88	0.85	0.82	0.79	0.76	0.73
	70	1.04	1.00	0.96	0.93	0.89	0.86	0.83	0.80	0.77	0.74	0.71	0.69
	100	.98	0.95	0.92	0.88	0.85	0.81	0.78	0.75	0.73	0.70	0.68	0.65
	150	.90	0.87	0.84	0.81	0.78	0.75	0.72	0.69	0.67	0.65	0.62	0.60
	200	.83	0.80	0.77	0.74	0.71	0.69	0.66	0.64	0.62	0.60	0.57	0.55
	250	.77	0.75	0.72	0.70	0.67	0.64	0.62	0.60	0.58	0.56	0.58	0.51
	300	.72	0.70	0.67	0.65	0.62	0.60	0.58	0.56	0.54	0.52	0.50	0.48
	350	.68	0.65	0.62	0.60	0.58	0.56	0.54	0.52	0.51	0.49	0.47	0.45
	400	.64	0.62	0.60	0.57	0.55	0.53	0.51	0.49	0.48	0.46	0.44	0.42
	450	.60	0.58	0.56	0.54	0.52	0.50	0.48	0.46	0.45	0.43	0.42	0.40
	500	.57	0.55	0.53	0.51	0.49	0.47	0.45	0.44	0.43	0.41	0.39	0.38
	550	.54	0.53	0.51	0.49	0.47	0.45	0.44	0.42	0.41	0.39	0.38	0.36
	600	.52	0.50	0.48	0.46	0.45	0.43	0.41	0.40	0.39	0.37	0.35	0.34
	700	.47	0.46	0.44	0.43	0.41	0.39	0.38	0.37	0.35	0.34	0.33	0.32
	800	.44	0.42	0.40	0.39	0.37	0.36	0.35	0.33	0.32	0.31	0.30	0.29
	900	.40	0.39	0.37	0.36	0.35	0.33	0.32	0.31	0.30	0.29	0.28	0.27
	1000	.37	0.36	0.35	0.33	0.32	0.31	0.30	0.29	0.28	0.27	0.26	0.25

Standard Air Density, Sea Level, 70 F = 0.075#/ft^3

SOURCE: ACGIH VENT MANUAL, 18TH EDITION

3.4 Hood Static Pressure

Hood Static Pressure (SPh) is perhaps the most useful measurement you can obtain.

Hood static pressure, SPh, is easily measured and can reveal a great deal about a local exhaust ventilation system. Surprisingly, hood static pressure is often misunderstood, and its usefulness is not always appreciated.

What is hood static pressure, SPh?

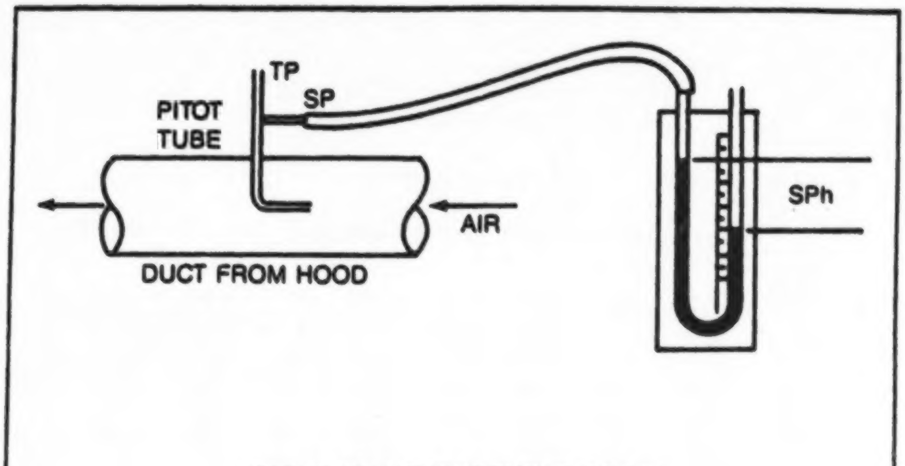
Hood static pressure represents (1) the energy required to accelerate the air from rest outside the hood to duct velocity inside the duct, and (2) the losses associated with hood/duct entry, known as the hood entry loss, He. Numerically, SPh can be expressed as

$$SPh = VP\ (duct) + He \qquad \text{(absolute values)}$$

Measuring hood static pressure

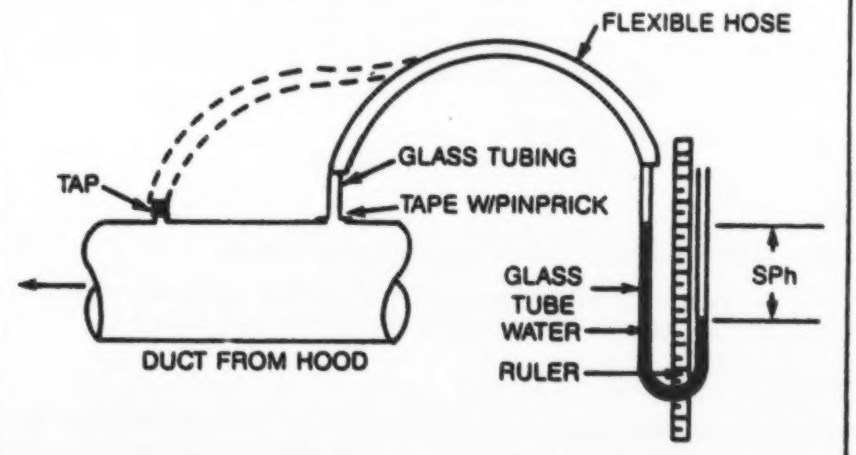
Hood static pressure is measured through a small hole, ideally about ten duct diameters (but more practically about 3–6 duct diameters) downstream from the hood in a straight section of duct.

Hood static pressure can be measured with a pitot tube and a U-tube manometer or other devices. See Figure below. SPh is the difference in the water level in the U-tube manometer, measured in inches of water.


TP
SP
PITOT TUBE
AIR
DUCT FROM HOOD
SPh

PITOT TUBE MEASUREMENT OF SPh

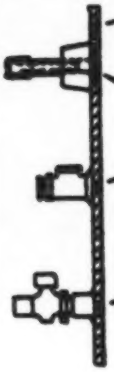
If a pitot tube is not available, an adequate estimate of hood static pressure can be obtained using a short length of copper or glass tubing, tape, some rubber hose, a piece of glass tubing bent into a U-shape, and a ruler. See Figure below. The measurement must be taken with an air-tight seal between the tubing and the tape. A little moisture, oil, or grease will help. If a more permanent fixture is desired, a hose tap can be soldered to the duct. The tap hole, in either case, should be smooth with no projections into the air stream.


FLEXIBLE HOSE
GLASS TUBING
TAP
TAPE W/PINPRICK
GLASS TUBE
WATER
RULER
SPh
DUCT FROM HOOD

MEASUREMENT USING AVAILABLE MATERIALS

The static pressure hole is of some importance in obtaining a correct pressure measurement. The location of the static pressure opening is not usually of too much importance except that one should avoid, if possible, pressure measurement at the heel of an elbow or other such points where static pressure may be incorrect because the direction of the velocity component is not parallel with the pipe walls. Drill from two to four pressure holes at uniform distances around the pipe in order to obtain an average and to indicate any discrepancy.

The static pressure openings should be flush with the inner surface of the pipe wall and there should be no burrs or projections on the inner surface. The hole should be *drilled*, not punched.



Duct wall — drill all holes 1/16" D. or less. Maintain inner surface of duct smooth and flush.

One hole rubber stopper, connecting tube and rubber hose.

Permanent top—1/8" tee with 1/8" pipe plug, T-handle and cleaning wire. Equip with 1/8" plug when not in use. Use 1/8" coupling if used for permanent connection to U-tube.

1/8" petcock and coupling with 3/16" copper tube soldered to petcock. Use carefully when high pressures are measured to prevent gauge liquid surge on opening cock.

STATIC TAP CONNECTIONS

SOURCE: ACGIH VENT MANUAL, 18TH EDITION

Hood static pressure is a good indicator of the air flow rate through the hood. If the hood itself has not been altered but the hood static pressure has changed, then airflow in the hood has changed.

Air volume changes are related to hood static pressure through the fan laws.

$$Q\ (\text{new}) = Q\ (\text{initial}) \left(\frac{\text{SPh (new)}}{\text{SPh (initial)}}\right)^{1/2}$$

EXAMPLE 1. Assume a hood is exhausting 10,000 cfm of air and the hood static pressure was measured at 3.0 inch w.g. Three months later the hood static pressure is 1.0 inch w.g. Assuming continued standard conditions (70-degrees F, 29.92 inch Hg) air flow through the hood has been reduced by how much?

Initial Conditions	New Conditions
SPh = −3 inch w.g.	SPh = −1 inch w.g.
Q = 10,000 cfm	Q = ?

$$\begin{aligned} Q\ (\text{new}) &= 10{,}000\ \text{cfm} \left(\frac{-1\ \text{inch}}{-3\ \text{inch}}\right)^{1/2} \\ &= 10{,}000\ (0.577) \\ &= 5{,}770\ \text{cfm} \end{aligned}$$

Hood static pressure is useful for estimating a hood's ability to convert static pressure into velocity pressure VP, which is directly related to air flow rate.

Between 40-90% of the hood static pressure is converted to useful flow in the form of velocity pressure. One measure of hood efficiency (the ratio of actual flow to ideal flow) is the coefficient of entry, Ce. Ce and He can be related to SPh through the following formulas.

$$He = SPh - VP$$

$$Ce = (VP/SPh)^{1/2}$$

where hood static pressures are given in absolute values.

Once established, the Coefficient of Entry never changes unless the hood shape physically changes. For example, if the sheet metal of the hood is cut or dented, the Coefficient of Entry will be altered.

EXAMPLE 2. Assume the original velocity pressure of the 10,000 cfm system was 1.2 inch w.g., and the coefficient of entry is 0.63 (actual flow is 63% of the ideal flow because not all the static pressure was converted to velocity pressure.)

If the hood static pressure three months later had dropped from 3 inch w.g. to 1 inch w.g., the new velocity pressure could be estimated by solving for VP in the Coefficient of Entry equation.

Initial Conditions	New Conditions
SPh = −3 inch	SPh = −1 inch
Ce = 0.63	Ce = 0.63
VP = 1.2 inch	VP = ?

$$\begin{aligned} VP &= Ce^2\,(SPh) \\ &= (0.40)(1) \\ &= 0.40 \text{ inch w.g.} \end{aligned}$$

Hood static pressure is also useful for estimating the flow rate in hoods. One formula for the flow rate at standard conditions is

$$Q = 4{,}005\ A\ Ce\ (SPh)^{1/2}$$

Hood static pressure is first measured. The coefficient of entry can be estimated from various references, such as the ACGIH VENT MANUAL, or can be obtained from the hood supplier or manufacturer.

EXAMPLE 3. Assume the hood static pressure in a 6" duct is 2.5 inch w.g., and the hood manufacturer indicates that Ce is 0.90; using the above equation, what is the estimated flow rate?

Operating Conditions

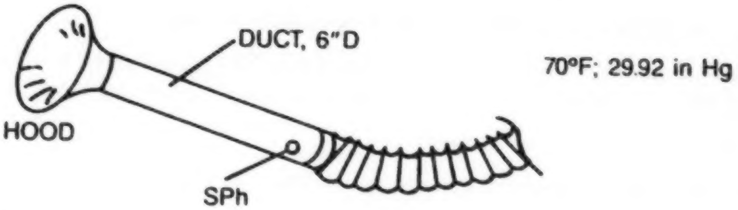
SPh = 2.5 inch w.g. (absolute value)

Ce = 0.90

A = 0.1964 sq.ft. for a six-inch duct

$$Q = (0.1964)(4{,}005)(0.90)(2.5)^{1/2}$$

$$= 1{,}120 \text{ cfm}$$



Daily inspection and maintenance

Because SPh is simple to measure, it is not difficult to equip a hood with a permanent manometer for continuous evaluation of the hood. It's easy to train workers to read the manometer. ("If you see the water level drop below 2 inches on the gauge, call me.")

4.0 MAINTENANCE

Persons involved with industrial ventilation should take an active interest in O&M—operation and maintenance of the system. A good O&M program will do the following:

- Maintain effectiveness of the system over time.
- Continue to protect employees and to comply with local and national standards.
- Help retain the value of the system.

It is amazing to see systems initially costing thousands of dollars left to deteriorate, sometimes in only a few weeks or months.

Elements of an O&M Program

First, get it on paper. No program survives unless it is a written program.

Second, establish a safe place to file away drawings, specifications, fan curves, operating instructions, and other papers generated during design, construction, and testing.

Third, establish a program of periodic inspection. It might go something like this—

- *Daily:* Visual inspection of hoods, ductwork, access and cleanout doors, blast gate positions, hood static pressure, pressure drop across air cleaner, and verbal contact with users. ("How's the system performing today?")
- *Monthly:* Air cleaner, fan housing, pulley belts, stack.
- *Routinely, as necessary:* Air cleaner components, motor, fan blades.

The frequency of inspection depends on the type of operation and other factors. The inspector can be one of the workers, a maintenance person, a foreman, or the industrial hygienist.

The next page shows a typical inspection checklist. It should be used only by those qualified by training and experience to inspect a ventilation system. It is provided here as a sample of a checklist you might develop for your operations.

Here's a way to check ducts for settled material: Take a broomstick and tap the underside of all horizontal ducts. (Better stand back, duct hangers are not designed to hold ducts full of particulate.) If tapping sounds like sheet metal—it's probably clear. If the tapping produces heavy, thudding sounds—no sheet metal vibration—there may be settled or caked dust in the duct.

Fourth, establish a preventive maintenance program. Certain elements of any system should be checked and replaced if defective, or replaced on a regular schedule, e.g., bags in a baghouse, fan blades, elbows.

Fifth, provide worker training. Show them how to work safely and how to best utilize the ventilation system. Mobile welding exhaust hoods do little good if the welder does not move the hood close to the work, for example.

Sixth, keep written records of all activities associated with the system. You may be transferred, or promoted. The next person, or a consultant called in to help, will want to know the history of the system.

LOCAL EXHAUST OR SANITARY VENTILATION SYSTEM CHECKLIST

1. Evaluation Equipment

( ) Paper, pencil, recording device
( ) Smoke generator, smoke tubes, smoke candle
( ) Velometer, air velocity meter
( ) Pitot tube, manometer, hoses
( ) Tape measure
( ) Flashlight
( ) Ladder
( ) Rags
( ) Watch
( ) RPM meter
( ) Sound-level meter, vibration meter

2. Background Data

( ) Original design specs and drawings
( ) Original operating specs
( ) Mods since installation
( ) Previous inspections/evaluations
( ) System controls
( ) Personnel to contact
( ) Maintenance schedules
( ) Fan curves
( ) Air cleaner specs

3. Employee Information

( ) Complaints
( ) Suggestions
( ) Comments
( ) Observed Work Practices
( ) Interaction with control
( ) Interaction with emission source
( ) Training/cooperation

4. Emission Source Characterization

( ) Location of emissions
( ) Rates of emission over time
( ) Chemical characteristics
( ) Physical characteristics
( ) Employee exposure levels
( ) Emission initial velocity
( ) Null point
( ) Environment
( ) Emission contribution to exposure

5. Hood, Capture Device

( ) Enclose, receive, capture
( ) Capture velocity
( ) Face velocity
( ) Performance during normal conditions
( ) Performance during abnormal conditions
( ) Compatibility with work practices
( ) Physical integrity
( ) Competing air movement
( ) Hood static pressure
( ) Hood entry loss
( ) Coefficient of entry
( ) Overall effectiveness

6. Piping and Ductwork

( ) Physical integrity
( ) Unplugged ductwork
( ) Transport velocities at design spec
( ) Duct material
( ) Blast gates, dampers set

7. Air Cleaners, Separators

( ) Physical integrity
( ) Static pressure drop
( ) Waste stream handling
( ) Maintenance and Operation

8. Fan, Air Mover

( ) Application of type
( ) Direction of rotation
( ) Speed, rpm
( ) Pulleys, belts
( ) Fan blades
( ) Fan housing
( ) Flexible couplings
( ) Access doors
( ) Inlet, outlet
( ) Weather protection
( ) Safety
( ) Fan curves
( ) Fan SP, Fan TP
( ) Bearings
( ) Vibration isolation

9. Motor

( ) RPM
( ) Rated HP
( ) Amperage draw
( ) Actual SHP
( ) Drive
( ) Temperature

10. Make-up Air

( ) Type
( ) Location of intakes
( ) Location of outlets
( ) Heat source, air distribution
( ) Interference with capture
( ) Force on external doors
( ) Drafts at exterior walls

11. Recirculation System

( ) Type
( ) Primary separator
( ) Secondary separator
( ) Back-up system
( ) By-pass
( ) Monitoring or warning system
( ) Maintenance

12. Hot Process Control Hoods

( ) Receiving
( ) Flow rates, face and duct
( ) Arriving velocities
( ) Arriving face area/hood area
( ) Surge
( ) Temperature

13. Plenum Systems

( ) Velocity
( ) Plugging
( ) Blast gates, dampers
( ) Explosion, fire protection
( ) Removal of settled materials
( ) Physical integrity

14. Measurements and Calculations

( ) Hood static pressure
( ) Capture velocity
( ) Hood face velocity
( ) Duct diameter, length
( ) Duct velocity
( ) Flow rate
( ) Fan SP
( ) Fan TP
( ) Fan RPM
( ) Motor RPM
( ) Motor amperage
( ) System static pressures

5.0 TROUBLESHOOTING A SYSTEM

Invariably, something goes wrong with almost all ventilation systems. All too often nothing is done because the trouble cannot be accurately diagnosed.

The following is a list of some common maladies and their potential sources.

Condition: Reduced capture velocities, excessive fugitive emissions.

Possible Causes: The cause is probably reduced flow rate (unless of course the process itself has changed). Reduced flow rate may occur in any of the following situations.

— plugged or dented ducts
— slipping fan belts
— open access doors
— holes in ducts, elbows
— closed blast gate to branch, or opened blast gates to other branches
— fan turning in reverse direction (This condition may occur when lead wires are reversed, thus causing the motor and fan to turn backwards. Centrifugal fans turning backwards may deliver up to 50% of rated capacity.)
— worn out fan blades
— additional branches or hoods added to system
— clogged air cleaner

Condition: Constant plugging of duct.

Possible Causes: Plugging of ducts occurs when there is inadequate transport velocity, or when condensation of vapor in the duct is wetting particles, causing a build up of material. These are the result of poor design, open access doors closer to the fan, fan problems, or any of the other problems listed above.

Condition: Excessive employee exposures, but flow volumes and capture velocities are at design levels.

Possible Causes: Work practices are incorrect; the ventilation system interferes with work or worker productivity so workers avoid use of system; employees are not cooperating; employee training is not adequate; poor initial design.

Condition: Worker complaints, misuse of system, non-use of system, alteration of system by employees.

Possible Causes: The hood interferes with work; the hood provides poor control of contaminants.

SOURCES: ACGIH VENT MANUAL, 18TH EDITION AND COMPANION STUDY GUIDE, ACGIH, 2ND EDITIO